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IEA District Heating And Cooling  
Programme of Research, Development and Demonstration on  
District Heating and Cooling including the integration of CHP

## **Promotion and Recognition of DHC and CHP Benefits in Greenhouse Gas Policy and Trading Programs**

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Sven Werner, FVB-Fjärrvärmebyrån  
Mark Spurr, FVB Energy Inc.  
Christine Pout, BRE

Contractor:

FVB-Fjärrvärmebyrån ab, Isolatorvägen 8, SE-721 37 Västerås, Sweden  
[www.fvb.se](http://www.fvb.se)

Sub-contractors:

FVB Energy Inc., Suite 340, 150 South Fifth Street, Minneapolis,  
MN 55402-4215, USA  
[www.fvbenergy.com](http://www.fvbenergy.com)

BRE-Building Research Establishment, Energy Division, Bucknalls Lane,  
Garston, Watford, WD25 9XX, United Kingdom  
[www.bre.co.uk](http://www.bre.co.uk)

International Energy Agency,  
Programme of Research, Development and Demonstration  
on District Heating and Cooling including the integration of CHP

Promotion and Recognition of DHC and CHP Benefits  
in Greenhouse Gas Policy and Trading Programs

by  
Sven Werner, Mark Spurr and Christine Pout

This report is the final result from a project performed within the Implementing Agreement on District Heating and Cooling, including the integration of CHP. However, this report does not necessarily fully reflect the views of each of the individual participant countries of the Implementing Agreement.

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# Executive summary

## DHC/CHP benefits

DHC and CHP provide a variety of opportunities to reduce emissions of greenhouse gases (GHG) and air pollution and increase energy security. The fundamental idea of DHC is to use local fuel or energy resources that would otherwise be wasted in order to satisfy local customer thermal energy requirements. Examples of local energy resources include thermal energy from combined heat and power (CHP) plants, refuse incineration plants, waste heat from industrial processes, natural geothermal heat sources, wood waste, and cold sea or lake water.

The ability of DHC networks to use local heat sources is of great national and international value in achieving reductions in emissions of air pollution and GHG such as carbon dioxide (CO<sub>2</sub>). DHC and CHP also enhance energy security in a variety of ways, including:

- increasing fuel supply reliability by using indigenous fuels like biomass or waste;
- strengthening power grid reliability by generating power near load centres;
- reducing power demand by supplying heating or cooling energy through DHC systems rather than the power grid; and
- shifting power demand to off-peak periods through thermal energy storage.

Annually, about 11-12 EJ heat are generated and delivered to district heating systems in the world. The corresponding heat deliveries represent about 5 % of the total final energy demand in the industrial, residential, public, and commercial sectors. This fraction is lower in the OECD-countries (2 %) and higher in the non-OECD-countries (7 %).

Globally, DHC/CHP including industrial CHP reduces existing CO<sub>2</sub> emissions from fuel combustion by 3-4%, corresponding to an annual reduction of 670-890 Mton compared to 1998 global annual emissions of 22700 Mton. The lower estimate is based on IEA Energy Balances for 1998. The higher estimate considers the lack of adequate information in the IEA Energy Balances about heat generation from industrial CHP in the EU and USA and power generation from CHP plants in China. The highest fractions of avoided carbon dioxide emissions from DHC/CHP occur in Russia (15%), in the former USSR outside Russia (8%) and in the EU (5%).

For the future, DHC/CHP can make further reductions of global carbon dioxide emissions. This can be accomplished by:

- increasing the market penetration of DHC through new and expanding existing DHC systems;
- increasing the share of CHP in existing DHC generation, since only 48% is currently produced from CHP; and
- fuel substitution in existing DHC/CHP plants, since coal constitutes 38% of fuel supplied.

## Future competitiveness of DHC and CHP

In the short term, the combination of DHC and CHP is a carbon-lean technology that will gain initial competitive strength from emissions trading systems. Hence, the contribution from DHC and CHP can be significant for fulfilling the Kyoto commitment for 2008-2012. An effective international system for carbon trading will facilitate realisation of this potential, since the marginal production in the current international electricity markets has high carbon dioxide emissions, due to the extensive use of coal as fuel (38% globally) and the low power plant efficiencies (33% is the global average).

This advantage with respect to carbon dioxide emissions will be weaker in the longer term. When the marginal production in international electricity markets achieves higher efficiencies and lower emissions, conventional district heating using CHP plants with fossil fuels will lose competitive strength. However, this is not a unique situation for DHC and CHP; it will apply to all carbon-lean technologies, since the future competition will not come from carbon-rich technologies, but from other carbon-lean technologies.

### Emissions trading systems

GHG emissions trading will be a key element in the implementation of Kyoto Protocol, based on the legal and political basis established in the Marrakesh Accords. Although the United States has opted out of the Kyoto process, other nations have moved toward implementation including progress toward development of GHG emissions trading. International emissions trading will take place under a cap-and-trade system, although the Protocol has also established two project-based mechanisms under which emission reduction credits can be generated through comparison of project emissions to a baseline of estimated emissions without the project.

The European Commission (EC) has published a directive on greenhouse gas trading following input from stakeholders, including this IEA project, on the EC "Green Paper" on emissions trading. The EU trading scheme is expected to begin operating in 2005. The sectoral coverage of the Directive builds on the framework arising from the Integrated Pollution Prevention and Control (IPPC) Directive. However, power and heat generators of a smaller size (20-50 MW) will also be included in the trading scheme, as urged in the comments provided by this IEA project.

Denmark and the United Kingdom have already begun operating national emissions trading schemes. National trading systems have been investigated in other countries including Sweden, Norway, Germany and Canada. Some companies, such as British Petroleum and Shell, have developed their own internal trading systems.

### Recommendations for emissions trading program design

When energy from DHC and/or CHP flows from one legal entity or sector to another, there is the potential that the emissions trading scheme will not recognize or credit the related emission reduction. Boundary issues arise in several contexts:

- whether or not the sector is included in the trading scheme; and
- whether an entity initiating an action that results in GHG reduction has ownership and/or control over the facilities in which the emission reduction takes place.

Without some mechanism for crediting offset building boiler emissions, emissions trading will place DHC at a disadvantage unless strong policies and measures applied to the buildings sector (which is not expected to be included in most emissions trading schemes). Emission trading schemes will constrain CHP without a means of crediting CHP projects developed by third party CHP developers (who then sell the power to the grid and heat to a DHC company or other entity).

The most important issue relates to quantification of emission reductions resulting from reduced demand on the power grid (often called "indirect emission reductions"). This is an important issue not only for CHP but also for demand-side management and renewable power generation technologies. In an increasing complex, dynamic and market-based power supply system, it is increasingly difficult to determine the emissions implications of reduced power demand on the grid plant mix. Establishing an appropriate value for indirect emission reductions is a key issue for project-based trading schemes, for CHP as well as other efficiency and renewable technologies.

### Other recommendations

As policy initiatives, such as the European Union's CHP Directive, the UK CHP initiative and the US CHP Challenge are developed, it is essential that these initiatives include strong and effective measures that address barriers to implementation of DHC and CHP.

Steps should be taken now to internalise the environmental and energy security benefits of DHC and CHP. This is important in order to:

- mitigate the environmentally negative impacts of energy market liberalisation;
- internalise in the marketplace the GHG reduction benefits of DHC/CHP in advance of a fully functioning GHG emissions trading scheme; and
- internalise air pollution and energy security benefits of DHC/CHP.

Recommended actions include implementation of a strong EU CHP Directive, and similar measures outside of the EU, to:

- establish CHP implementation targets;
- ensure access, under transparent and non-discriminatory terms, to the power grid; and
- encourage energy and CO<sub>2</sub> tax schemes that at the very least do not discriminate against DHC and CHP, and preferably would provide positive incentives.

# Preface

## Introduction

The International Energy Agency (IEA) was established in 1974 in order to strengthen the co-operation between member countries. As an element of the International Energy Programme, the participating countries undertake co-operative actions in energy research, development and demonstration.

District heating and cooling (DHC) offers excellent opportunities for achieving the twin goals of saving energy and reducing environmental pollution. It is an extremely flexible technology which can make use of any fuel including the utilisation of waste energy, renewables and, most significantly, the application of combined heat and power (CHP). It is by means of these integrated solutions that very substantial progress towards environmental targets, such as those emerging from the Kyoto commitment, can be made.

For more information about this Implementing Agreement please check our Internet site [www.iea-dhc.org/](http://www.iea-dhc.org/)

## Annex VI

In May 1999 Annex VI started. The countries that participated were: Canada, Denmark, Finland, Germany, Korea, The Netherlands, Norway, Sweden, United Kingdom, and United States of America.

The following projects were carried out in Annex VI:

<b>Title project</b>	<b>ISBN number</b>	<b>Registration number</b>
Simple Models for Operational Optimisation	90 5748 021 2	S1
Optimisation of a DH System by Maximising Building System Temperatures Differences	90 5748 022 0	S2
District Heating Network Operation	90 5748 023 9	S3
Pipe Laying in Combination with Horizontal Drilling Methods	90 5748 024 7	S4
Optimisation of Cool Thermal Storage and Distribution	90 5748 025 5	S5
District Heating and Cooling Building Handbook	90 5748 026 3	S6
Optimised District Heating Systems Using Remote Heat Meter Communication and Control	90 5748 027 1	S7
Absorption Refrigeration with Thermal (ice) Storage	90 5748 028 X	S8
Promotion and Recognition of DHC/CHP benefits in Greenhouse Gas Policy and Trading Programs	90-5748-029-8	S9

## **Benefits of membership**

Membership of this implementing agreement fosters sharing of knowledge and current best practice from many countries including those where:

- DHC is already a mature industry
- DHC is well established but refurbishment is a key issue
- DHC is not well established.

Membership proves invaluable in enhancing the quality of support given under national programmes. The final materials from the research are tangible examples, but other benefits include the cross-fertilisation of ideas which has resulted not only in shared knowledge but also opportunities for further collaboration.

Participant countries benefit through the active participation in the programme of their own consultants and research organisations. Each of the projects is supported by a team of Experts, one from each participant country. The sharing of knowledge is a two-way process, and there are known examples of the expert him/herself learning about new techniques and applying them in their own organisation.

## **Information**

General information about the IEA Programme District Heating and Cooling, including the integration of CHP can be obtained from:

IEA Secretariat  
Mr. Hans Nilsson  
9 Rue de la Federation  
F-75139 Paris, Cedex 15  
FRANCE  
Telephone: +33-1-405 767 21  
Fax: +33-1-405 767 49  
E-mail: hans.nilsson@iea.org

or

The Operating Agent  
NOVEM  
Ms. Marijke Wobben  
P.O. Box 17  
NL-6130 AA SITTARD  
The Netherlands  
Telephone: +31-46-4202322  
Fax: +31-46-4528260  
E-mail: m.wobben@novem.nl

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# Introduction

## DHC Definition

District heating systems distribute hot water or steam from a central plant to individual buildings through a network of pipes to supply space heating, domestic hot water and/or industrial process energy. City-wide district heating systems exist in Helsinki, Stockholm, Copenhagen, Berlin, Munich, Hamburg, Paris, Prague, Moscow, Kiev, Warsaw and other 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 industrial area.

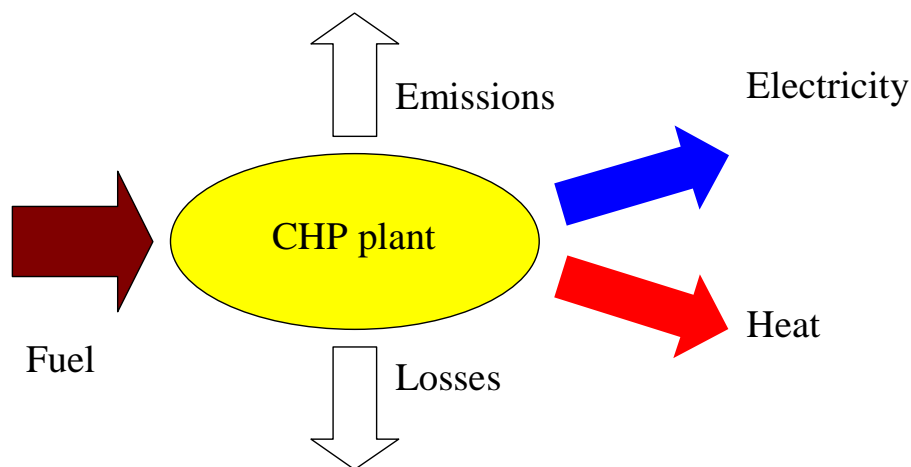
District cooling systems, distribute chilled water or other heat transfer media (e.g., glycol) to supply air conditioning or process cooling. These systems are seldom city-wide systems. Major downtown districts with district cooling systems exist, such as in Stockholm, Hamburg, Paris, Chicago, Minneapolis, St. Paul, New Orleans, Houston and other cities.

District heating and cooling systems are collectively abbreviated “DHC” and are sometimes also called “district energy systems.”

DHC systems provide “ready-to-use” thermal services for buildings, rather than electric energy or fuel that must be converted to thermal services on-site. DHC systems can supply thermal energy to buildings directly (by circulating DHC water through the building) or indirectly by transferring energy to the building systems through a substation. In contrast, conventional on-site heating and cooling systems typically require combustion of fuel in a boiler and/or use of electrically-driven equipment to produce heating and/or cooling. DHC service eliminates the need such for on-site conversion by delivering hot water, steam and/or chilled water directly to buildings.

## CHP Definition

Combined heat and power (CHP) is the simultaneous or sequential generation of electricity, mechanical shaft power, or both, in combination with the generation of steam, hot water or other forms of useful thermal energy. CHP, also called “cogeneration,” is a general term that encompasses a wide variety of technologies including steam turbines, combustion turbines, reciprocating engines and fuel cells. **Figure 1** is a general illustration of the CHP process. Recovered heat can be used for heating or can be converted to cooling using absorption chillers or steam turbine chillers.



*Figure 1. General description of the five major flows of a CHP plant*

## **Project Purpose**

DHC and CHP can make significant contributions to reducing emissions of greenhouse gases (GHG), particularly carbon dioxide (CO<sub>2</sub>), in order to meet the targets established in the Kyoto Protocol. One of the key “flexibility mechanisms” of the Kyoto Protocol is international emissions trading, which allows a country with an excess of emission units, resulting from reduction of emissions below commitment levels, to sell its credits to another country unable to meet its commitments.

This project was undertaken to promote the benefits of DHC and CHP during a period when it was anticipated that significant progress would be made in development of GHG policies and related international and national structures for emissions trading. Specifically, the purpose of this project was to promote the environmental benefits of DHC and to identify and encourage policies and emissions trading program structures that recognize and reward the emission reduction benefits of DHC and CHP.

## **Communication**

Information has been gathered for the project and presented from the project at the following seminars and conferences:

- The Euroheat & Power Emissions Trading Seminar. Brussels, Belgium, September 4, 2000. (Mark Spurr and Sven Werner)
- The international seminar about CHP at The Swedish Energy Forum. Eskilstuna, Sweden, March 14, 2001. Sven Werner: Efficient communication of the benefits of CHP with respect to lower carbon dioxide emissions.
- Second International CHP Symposium. Amsterdam, the Netherlands, May 9, 2001. Mark Spurr: Role of District Heating & Cooling and Emissions Trading in Expanding Use of CHP.
- 30<sup>th</sup> Congress of Euroheat & Power. Gdansk, Poland, June 8, 2001. Sven Werner: Rewarding Energy Efficiency: The Perspective of Emissions Trading. The presentation has been slightly revised and published in *Fernwärme International* (2001):9, 14-21. This journal is the only major journal for DHC and CHP in Europe, [www.vwev.de](http://www.vwev.de)
- CATEP Workshop on Trading Scales: Linking Industry, Local/Regional, National and International Emissions Trading Schemes. Venice, Italy, December 3-4, 2001. (Mark Spurr)
- GHG Emissions Trading Mock Negotiation Workshop, conference sponsored by Climate Change Central. Calgary, Alberta, Canada, February 21, 2002. (Mark Spurr)
- Euroheat & Power conference POWER TO THE HEAT –Energy efficiency for Europe made by CHP, District Heating and Cooling. Brussels, Belgium, March 5, 2002. Sven Werner: CHP/DHC within an European scheme for emissions trading.
- The 8th International Symposium on District Heating and Cooling. Trondheim, Norway, August 15, 2002. Mark Spurr and Sven Werner: Promotion and Recognition of DHC and CHP Benefits in Greenhouse Gas Policy and Trading Programs.

# Benefits of DHC and CHP

## DHC Benefits

The fundamental idea of DHC is to use local fuel or energy resources that would otherwise be wasted in order to satisfy local customer thermal energy requirements. Examples of local energy resources include thermal energy from CHP plants, refuse incineration plants, waste heat from industrial processes, natural geothermal heat sources, wood waste, and cold sea or lake water. In the context of CHP, referring to **Figure 1**, the strength of DHC is its ability to take what would otherwise be losses, convert this to useful energy and transport it to thermal energy users.

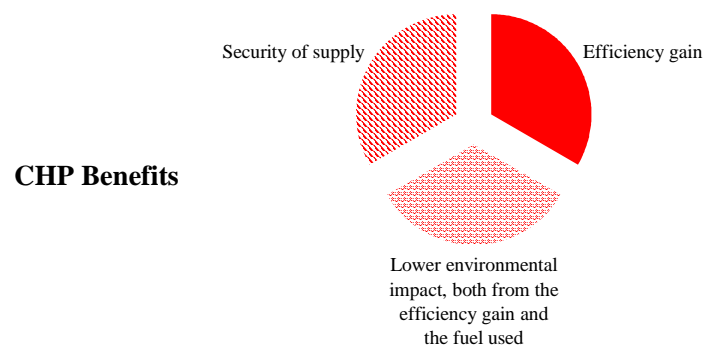
The ability of DHC networks to use local heat sources is of great national and international value in achieving reductions in emissions of air pollution and GHG such as carbon dioxide (CO<sub>2</sub>). DHC and CHP also enhance energy security in a variety of ways, including:

- increasing fuel supply reliability by using indigenous fuels like biomass or waste;
- strengthening power grid reliability by generating power near load centres;
- reducing power demand by supplying heating or cooling energy through DHC systems rather than the power grid; and
- shifting power demand to off-peak periods through thermal energy storage.

Annually, about 11-12 EJ heat are generated and delivered to district heating systems globally. The corresponding heat deliveries represent about 5 % of the total final energy demand in the industrial, residential, public, and commercial sectors. This fraction is lower in the OECD-countries (2 %) and higher in the non-OECD-countries (7 %).

## CHP Benefits

The use of CHP has three major benefits: efficiency gain, lower environmental impact, and security of supply, as illustrated in **Figure 2**.



**Figure 2.** The three major benefits of CHP

The efficiency gain comes from, for example, the higher conversion efficiency from CHP generation compared to separate generation of electricity and heat in condensing thermal power plants and local boilers for heating. The lower environmental impact is due to both the efficiency gain and the use of more carbon-lean fuels and renewable energy resources. The security of supply is higher for CHP plants since they generate power in urban areas near consumer demands, and with many small plants they are less vulnerable to major interruptions in supply.

Today, 48% of all heat generated centrally comes from CHP plants. This fraction is higher in OECD countries (75 %) than in non-OECD countries (41 %).

The benefits of DHC and CHP are further addressed in the policy presentations described below.

### **Policy Presentations**

A brief policy paper (**Appendix 1**) provides an overview of the benefits of DHC and CHP relative to climate change, air quality and energy security, and recommends supportive policies. A PowerPoint presentation on the benefits of DHC/CHP, and key emission trading program design issues, was prepared for the 2<sup>nd</sup> Annual CHP Symposium (Spurr 2001). This presentation has been updated to incorporate elements of the policy paper as well as the results of the analysis of DHC/CHP CO<sub>2</sub> reduction potential described in the following section. (See **Appendix 2**).

Both the policy paper and presentation are available for download at [www.iea-dhc.org](http://www.iea-dhc.org)

### **Global CO<sub>2</sub> Reduction Analysis for DHC/CHP**

Globally, DHC/CHP including industrial CHP reduces the existing carbon dioxide emissions from fuel combustion by 3-4%, corresponding to an annual reduction of 670-890 million metric tons (Mton) compared to global annual emissions of 22700 Mton. The lower estimate is based on IEA Energy Balances for 1998. The higher estimate considers the lack of adequate information in the IEA Energy Balances about heat generation from industrial CHP in the EU and USA and power generation from CHP plants in China. The highest fractions of avoided carbon dioxide emissions from DHC/CHP occur in Russia (15%), in the former USSR outside Russia (8%) and in the EU (5%).

The avoided global carbon emissions from existing DHC/CHP systems would have been 220 to 500 Mton higher if all CHP plants could operate with a minimum overall efficiency of 75 %. This corresponds to an overall reduction of 5 %. This increase is possible since the global average of the overall efficiency is only 51 % according to the IEA Energy Balances for 1998. The allocation of this efficiency is 27 % for electricity and 24 % for heat. Doubling the heat utilisation by expanding the corresponding local heat sales would result in an overall efficiency of 75 %.

These estimates of avoided carbon dioxide emissions from CHP/DHC have been made within this project. The complete analysis is presented in **Appendix 3**.

For the future, DHC/CHP can make further reductions of global carbon dioxide emissions. This can be accomplished by:

- increasing the market penetration of DHC generation through new and expanding existing district heating systems;
- increasing the share of CHP in existing DHC generation, since only 48% is currently produced from CHP; and
- fuel substitution in existing DHC/CHP plants, since coal constitutes 38% of fuel supplied.

# DHC/CHP in Policy Programs

## Certification of CHP

The liberalisation of the European electricity market strikes hard against existing CHP plants. Regional over-capacity has decreased power prices to levels below the cost for new power plants. As a result, the whole power industry suffers from lower return of capital invested. This situation is not unique for CHP plants, but applies to all forms of power generation. Many large coal condensing plants have been or will be closed.

The current recession in the electricity market has been extended to the district heating systems. Lower short-run marginal electricity prices results in a higher short-run heat cost in the internal cost allocation for the CHP plants. Hence, the fundamental economic benefits of CHP are currently too weak to expand the existing district heating systems in Europe. The financial benefit for CHP is low, giving a lower incentive for district heating from CHP plants.

However, CHP plants have one major advantage not yet priced by the market. They have lower carbon dioxide emissions than other fuel-based power stations and it is still free of charge to emit carbon dioxide to the atmosphere from power plants. In order for this advantage to be recognized, before emissions are priced through emissions trading systems, some interim benefits should be allocated to existing CHP plants. However, a certification process is needed in order to allocate the benefits to “good” CHP plants. Benefits to “bad” CHP plants should be avoided. This situation creates a need for definition and certification rules.

Certification of CHP plants is a vital element in both the UK good quality policy program CHPQA and the new German CHP law. The CHPQA program is presented in more details in **Appendix 6** and is also available at [www.chpqa.com](http://www.chpqa.com) website. The new German “Law on the Conservation, Modernisation and Development of Combined Heat and Power,” effective starting April 1, 2002, refers to the certification standard of (AGFW 2001).

## EU Directive for CHP

In the October 1997 CHP communication the European Commission established a goal of doubling CHP’s share of European power generation from 9 to 18 % (European Commission 1997). In this context a certification debate started, since many large power plants with small fractions of heat generation also were labelled as CHP plants in the Eurostat power statistics. The debate initiated a certification procedure documented in (Protermo 1999 and 2000 ) and a separate study of CHP generation in the European Union, published in (Eurostat 2001).

As a successor to the CHP communication, the European Commission announced in the ECCP communication in October 2001 its intention to present a CHP directive during 2002 (European Commission 2001b). The aim of the planned directive is to complement and strengthen existing measures to promote CHP in line with the Community target of doubling the market share for CHP electricity. In response to a background document and request for comment prepared by Directorate D of EC DG TREN (European Commission 2001d) relative to the planned directive, this IEA project provided comments and recommendations (**Appendix 4**).

## The European Climate Change Program

In 2001, the European Climate Change Program published estimates of carbon dioxide abatement potential of various abatement measures at different cost ranges (European Commission 2001a) The total CHP carbon reduction potential was estimated to 65 Mton/year. However, the estimated potential in the cost range under 20 Euro (about US\$18 at current exchange rates) per metric ton carbon dioxide was only 1 Mton/year. An additional 17 Mton/year was estimated to be reduced at a cost of 20-50 Euro (US\$18-45) per ton CO<sub>2</sub>. The majority of the potential (47 Mton/year) was estimated to occur in the 50-100 Euro (US\$45-90) per ton range. These estimates only consider industrial CHP and small-scale CHP in the residential, public and commercial sectors. CHP in

conjunction with DHC was not included as a separate measure and was therefore not considered as an option for reducing emissions.

The high abatement costs estimated for CHP result from the implementing situation in Europe, with over-capacity of power generation in Europe and thus relatively low market values for new power capacity. The methodology assumed that fuel substitution is first implemented in the power sector with new power plants (using gas). Secondly, renewables are introduced, and as the third measure in line, CHP is introduced. The ECCP did not consider that fuel substitution can be integrated with new CHP plants for existing DHC systems.

The ECCP significantly underestimated the potential for carbon dioxide reductions through CHP, in particular ignoring the potential to reduce carbon dioxide through CHP in conjunction with DHC. That potential is very significant. When combining both fuel substitution and the CHP technology, doubling the CHP market share in Europe will reduce carbon dioxide emissions by 194 Mton/year according to an estimation made in (Euroheat & Power 2001). Cogen Europe has also earlier published estimations of the same order.

# Emission Trading Programs

## International Emissions Trading

The Kyoto Protocol requires each participating nation to achieve specified reductions in emissions of GHG. The protocol addresses six categories of GHG: CO<sub>2</sub>, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. The Protocol establishes legally binding obligations for industrialised countries to reduce emissions of GHG during 2008-2012 in comparison to 1990 emissions. The reduction targets are expressed as “assigned amounts” for each industrialised country in Annex B of the Protocol.

The Kyoto Protocol includes three types of “flexibility mechanisms” that allow some of a nation’s reductions to take place outside that country’s borders:

- *International emissions trading (IET)*, in which developed countries (sometimes referred to as “Annex B” or “Annex 1” countries) are allocated “Assigned Amount Units (AAUs)” for GHG emissions consistent with its reduction commitment for the first commitment period of 2008-2012. If a Party’s actual emissions are lower than their AAU allocation, it will have excess allowances that it can then sell to another party for whom it would be less cost-effective to meet its reduction commitment within its borders. (Article 17)
- *Joint Implementation (JI)*, which allows Annex B countries to transfer or acquire emissions reduction units (ERUs) resulting from projects in other Annex B countries. (Article 6)
- *Clean Development Mechanism (CDM)*, which allows Annex B countries to acquire certified emissions reductions (CERs) resulting from projects in non-Annex B countries. (Article 12)

This report is focused on IET under Article 17, although issues related to JI and CDM are also addressed. Further, this report will primarily address CO<sub>2</sub> trading because the primary focus of trading program design has been on CO<sub>2</sub>.

IET is a “cap and trade” mechanism, in which emissions are capped for each Annex B country at its assigned amount. In contrast, JI and CDM are project-based mechanisms that measure reductions against a “baseline.” The baseline is often defined as the emissions that would occur in the absence of mitigation action, although it can also be defined to require some mitigation action.

The extent to which ERUs or CERs will be accepted by a domestic or regional trading program for the purpose of meeting Kyoto commitments is yet to be determined. As noted below, the EU has set aside this issue for future consideration. However, the CDM will be the first flexible mechanism to become operational, so the procedures adopted for the CDM could help set the standards for JI and IET.

The World Bank has established the Prototype Carbon Fund (PCF) to help create a market for ERUs and CERs. The primary focus is on renewable energy technologies that would not be profitable without financial support from the PCF.

Although the legal framework for emissions trading has not yet been fully developed, a growing number of companies and governments are trading emission reduction credits under a voluntary ad hoc framework involving a commodity defined by the trade’s participants and known as “verified emissions reductions” (VERs). To date, about 65 GHG trades for quantities above 1,000 tonnes of CO<sub>2</sub> equivalent (CO<sub>2</sub>e) have occurred worldwide since 1996, including trades of reductions as well as financial derivatives based on reductions (Rosenzweig 2002). The total volume of GHG emission trades during 2001 has been estimated to be about 10 Mtons CO<sub>2</sub>e and is projected to jump to about 100 Mton in 2002 (PointCarbon 2002a).

The first international trading between national programs occurred in early 2002, with Royal Dutch Shell swapping allowances with Elsam, Denmark’s largest power generator. Shell took Danish allowances from Elsam in return for UK allowances allocated to the Danish company.



## **Domestic Trading Schemes**

Domestic trading schemes provide the legal framework for emission source entities to participate in international trading directly and/or indirectly. Ultimately, participating national governments (the Parties under the Kyoto Protocol) are required to demonstrate compliance with their commitments under the Kyoto Protocol. However, under the rules adopted at COP7 in Marrakesh, Parties to the Kyoto Protocol may authorize companies to directly take part in international emissions trading.

The Marrakesh agreement requires that direct participation by entities in trading must be consistent with the international rules (e.g. legal entities may not trade if the authorizing Party fails to meet the eligibility requirements). Some countries, like the UK, intend to authorize such trading. However, others may not, which will mean all trades in those countries will have to be done indirectly, through and by the Party. In indirect participation, the international trading is undertaken by the governments, with the domestic scheme allowing an entity to benefit from an emissions trade by being allowed to emit more GHG from their operations than would be allowed without the trade.

Key elements of a domestic trading scheme include:

- Unit of trade: a certificate for emission metric tonne CO<sub>2</sub>
- Electronic certificate with unique serial number
- Issued in advance of each period
- Not valid unit that period
- Valid until used to offset emissions (bankable)
- Freely transferable
- Legal requirement for firm at point of obligation to hold and surrender certificates to offset emissions

The point of obligation could be

- Production or import of fuel/other inputs (upstream)
- Point of actual emission (downstream)
- Targeted at either point of input or emission depending on nature of sector (targeted)

Allocation of credits may take place based on:

- “Grandfathering” based on past emissions;
- Useful energy output on an updating basis; or
- Competitive auction.

## **Credit for Early Action**

A critical issue for design of GHG trading schemes is how to encourage early reductions in GHG emissions. This is a potentially difficult issue because early reductions could hurt a company depending on how emission allowances are allocated for the 2008-2012 period and succeeding commitment periods. If allowances are allocated based on grandfathering, early reduction would reduce a company’s allocation.

Early reduction programs are intended to encourage and reward companies that act soon to reduce GHG emissions before domestic GHG regulation begins. Key issues include:

- How and when will participants receive credit for early action?
- If allowances are allocated based on historic emissions, how to adjust participants’ baselines so that they are not penalized for early action?
- What will be the criteria for receiving credit?
- What formula will be established for calculating emission baselines?
- Who will receive credit when more than one entity is involved?

The proposed EU trading scheme, described below, addresses early action in the 2005-2007 period.

Some trades are taking place based on the hope that the government will implement a trading program that recognizes the value of these trades. Other trades are occurring as a result of

requirements attached to approvals for construction of power plants. In the absence of a specific legislative and legal framework for GHG emissions trading, companies are developing contractual arrangements to clarify rights and obligations relating to emission trades.

One mechanism that has been advocated to encourage renewable generation is “Green Certificates.” In this approach, sellers of electricity would be required to produce a certain percentage of power through renewable technologies. If their actual renewable generation was lower than the required amount, they would have to buy Green Certificates from generators with excess certificates resulting from high-than-required renewable generation.

This IEA project has advocated that the Green Certificate approach also be applied to CHP (see **Appendix 4**).

Early trades, in advance of a fully established legal and regulatory framework, present a variety of issues (Ezekiel and Wilson, 2002):

#### Verification

- What is the verification standard?
- How is access provided to verification-related data, and are all parties with necessary data part of the contract?
- Who bears the risks associated with future changes in the verification standard?
- What is the schedule for providing data and performing verification?
- Who performs the verification?
- Who bears the costs of verification?

#### Surplus (Regulatory Additionality)

- GHG reductions that are implemented due to other legal or regulatory requirements do not qualify for GHG trading, i.e. the reductions must be surplus or in addition to other requirements.
- Who bears the risk if a company implements a GHG reduction project absent other legal requirements, and then later new legal requirements eliminate the regulatory additionality of the project?

#### Force Majeure

- This refers to contractual provisions that absolve parties of obligations based on factors beyond their control.
- In the past, force majeure has generally been tied to natural disasters—“acts of God.”
- In recent years there has been a trend toward including other, lesser types of events in these clauses, e.g., reduction or elimination of operations of the thermal host operation for business reasons.

#### Vintage

- “Vintage” refers to the year in which emission reduction occurs.
- This is critical because the obligations of the Parties to the Kyoto Protocol are tied to the specific commitment periods, with the first commitment period occurring in 2008-2012.
- Certified emission reductions (CERs) received through the CDM are bankable, i.e. reductions achieved before 2008 can be used to meet obligations during the first commitment period.
- In early trades, until a domestic legal framework is established, there is uncertainty regarding the extent to which pre-commitment period reductions will be recognized.
- Generally sellers in an early trade will have an interest in maximizing inclusion of pre-2008 tons.
- Buyers may want to put the risk on the seller by requiring that if the pre-2008 reductions are not recognized that the seller provide additional 2008-2012 credits from the proposed project, or provide credits from other sources.

#### Security

- Emission trades are long-term agreements, thus increasing the risk that one of the parties won’t go out of business or otherwise not be able to perform.
- There are currently no insurance instruments available to ensure performance.
- It may be advisable to specify recourse in the contract, e.g. the seller might commit to replacing the reduction credits if they are unable to generate the credits through the proposed project, or specify a payment in lieu of the credits.

### CDM/JI

- In CDM deals, it is important to negotiate the terms of the host country recognizing the reduction in its progress report, as well as the buyer's country recognizing the CER's so that the entity's obligations for domestic reductions are reduced.
- Projects starting as of 1 January 2002 may be eligible for registration as a JI or CDM project.
- If accepted, some CDM projects could begin to generate CER's as of 1 January 2000, even if registered later.
- JI projects can only generate ERUs starting in 2008.

### **Status of Regional and National Trading Schemes**

#### *EU trading scheme*

The European Union (EU) is developing a GHG emissions trading program that is intended to facilitate cost-effective reductions in GHG emissions within the EU. Development of the program was initiated in March 2000, when the Environmental Directorate of The European Commission published a "Green Paper" (European Commission 2000a). The Green Paper constituted the start of a process of exploring the issues of a European emissions trading system of greenhouse gas emissions. Succinct reactions and opinions were requested, focused on the 10 questions contained in the Green Paper.

In response to the Green Paper, a joint position paper was prepared as a part of this IEA project, in cooperation with Euroheat & Power. (See **Appendix 5**.) These comments focused particularly on scope of the trading program relative to the sectors and facility sizes included, the allocation approach, and the balance between trading and other programs/measures.

Following input from this IEA project and other stakeholders, the European Commission published a directive on greenhouse gas trading (European Commission 2001c). The EU trading scheme is expected to begin operating in 2005. Each member state would be required to implement a domestic trading program with certain common elements. The EU trading scheme covers, in principle, all GHG emissions. However, initially only carbon dioxide emissions, from a variety of specific activities, will be included. By the end of 2004, the EC may make a proposal to include other activities and GHG in the trading program.

The Directive proposes to link GHG reduction with existing environmental legislation, allowing Member States to build on permitting procedures under the Integrated Pollution Prevention and Control (IPPC) Directive (European Parliament 1996). The sectoral coverage of the Directive builds on the framework arising from the IPPC Directive. However, power and heat generators of a smaller size (20-50 MW) will also be included in the trading scheme, as urged in the comments provided by this IEA project on the Green Paper. (See **Appendix 5**.) The scheme would cover 4000-5000 installations starting in 2008. During the 2005-2007 period a Member State could exempt facilities required to make an equivalent effort under domestic policies.

The Directive establishes common criteria for allocation. During the 2005-2007 period, allowances would be allocated without cost. By June 2006 the EC will review the experience gained to date and determine the most appropriate method for harmonised allocation for the 2008-2012 period. Member States would be required to publish their national allocation plan, provide for comments by the public and submit it to the Commission before taking any final decision, which must take account of public comments.

The Directive sets out principles for monitoring, reporting and verification of emission reductions, and establishes compliance penalties. During the commitment period, emissions in excess of allowances held would be penalised at 100 Euro per ton (about US\$90 at current exchange rates), or twice the average market price during a predetermined period, whichever is higher. During the precommitment period the penalty would be 50 Euro per ton (about US\$45) or twice the average market price during a predetermined period, whichever is higher.

The Directive requires that emissions trading be compatible with another market-based instrument being developed within several Member States: "Tradeable Renewable Certificates," also called "Green Certificates" as discussed above.

The Directive does not address the inclusion of credits from JI or CDM due to concerns about the environmental integrity of such credits. Following further development of rules covering JI and CDM, the EC intends to prepare a subsequent proposal in the form of a separate instrument on the implementation of project-based mechanisms in the EU.

#### *National trading schemes*

Denmark and the United Kingdom have already begun operating national emissions trading schemes. In the Netherlands, the ERU-PT program has been implemented to address JI projects. National trading systems have been proposed in Canada, Norway, Sweden, Germany, France, Switzerland, Slovakia and Australia. Some companies have developed their own internal trading systems, including British Petroleum and Shell. A voluntary pilot program involving a number of industrial companies has been implemented in Canada. This program, originally called the Pilot Emission Reduction Trading (PERT), has evolved into a new organisation called CleanAir Canada. In the U.S., a voluntary pilot program for GHG trading called Chicago Climate Exchange has been established, initially focussing on seven Midwestern states.

The UK emissions trading scheme and an analysis of related analytical issues is presented in **Appendix 6**.

The Danish trading scheme covers only the power sector, with a declining cap until 2003 (Pedersen 2000). Since CHP plants are also included in this sector, the total emissions from each plant must be allocated to power and heat generation. The benefit of CHP with respect to lower CO<sub>2</sub> emissions is not completely allocated to one of the two products, but shared. The CO<sub>2</sub> emissions associated with heat generation are subtracted from the total emissions by assuming a conversion efficiency of 200% for heat generated. If coal is used as fuel in the CHP plants, the heat generated is allocated an emission of  $92 / 200\% = 46$  g CO<sub>2</sub> per MJ heat. Assuming a heat distribution loss of 10%, this will be 51 g/MJ at the customer. The market alternative is to use natural gas in a local boiler with a conversion efficiency of 85 %, giving an alternative carbon dioxide emission of  $56 / 85\% = 66$  g per MJ heat. Thus, the Danish rules do not allocate more emissions to the heat market than the market alternative offers. This is good, because if this was not the case, a precedent would be set that could cause competitive problems for DHC plants when the emissions trading scheme is expanded to include the heat sector.

In 2000 the Netherlands government launched a program for providing funds for acquisition of ERUs from Eastern European countries, in the Emission Reduction Units Procurement Tender (ERU-PT) program. Through the program, the Dutch government buys emission reduction credits from JI projects in Central and Eastern Europe. A Memorandum of Understanding between the host country and the Dutch government will provide credit toward the Dutch Kyoto target for emission reductions during and after 2008 resulting from a project. In response to the first tender, the Dutch government purchased a total of 4 Mton of CO<sub>2</sub> (0.8 million tonnes per year) from five projects. Two of the projects were district heating projects in Romania. In a second round, 18 projects have been selected for evaluation, representing an emission reduction of 23 Mton CO<sub>2</sub>. The Dutch government has recently decided to extend the program to developing countries under the CDM, and has renamed the combined program Carboncredits.nl (Carboncredits.nl 2002).

Although a final decision on a Canadian trading scheme will not be made until the Kyoto Protocol is ratified, development of a scheme has begun by the Tradeable Permits Working Group (TPWG). The TPWG considered two possible approaches: 1) a downstream system covering only large emitters – about 700-900 firms representing 40-50% of Canada's total GHG emissions; and 2) a midstream or upstream system covering fossil fuel combustion, with 800-1000 participants representing over 80% of total emissions (Tradeable Permits Working Group 2000).

The Norwegian government published a White Paper in June 2001 in which rules were proposed for a domestic trading scheme (Haites & Mullins 2001). The program would begin in 2008, although an earlier start is possible depending on policies implemented by other countries. The system would be mandatory for 100-200 entities and would cover about 80% of total GHG emissions.

In April 2000 the report of a one-man commission on emission trading in Sweden was published (Swedish Ministry of Industry, Employment and Communications, 2000). The report was shaped by the EU Green Paper, and envisions a Swedish system starting in 2005 consistent with the EU program. The scheme would start with CO<sub>2</sub> emissions from six industrial sectors covering about 30% of total emissions, but would expand to all GHG in 2008. The report recommends that fossil

fuel wholesalers to the domestic and transport sectors be included, thereby increasing coverage to nearly 90% of emissions in 2008. The report recommends that the current CO<sub>2</sub> tax be phased out by 2005, and that GHG allowances be auctioned.

Investigation of how emissions trading could be implemented in Germany was initiated in October 2000 by the Arbeitsgruppe Emissionshandel zur Bekämpfung des Treibhaususeffektes (AGE), which included representatives of the Federal Government, Parliament, industry and environmental organizations (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2001).

Compilations of various existing and planned national emissions trading systems are presented in (Haïtes & Mullins 2001) and (Hasselknippe & Høiby 2001).

## **Prices**

To date, a very small number of GHG emissions trades have taken place. These trades have occurred prior to fully developed laws and regulations governing trades, or under newly established national programs. For Annex B VERs in vintage years 2008-2012, price ranges per ton of CO<sub>2</sub>e have been: US\$4.50-7.50 for Dutch ERU's (Carboncredits 2002) and US\$1.65-3.00 for other VERs (Rosenzweig 2002). Danish allowances (vintage 2001-2002) have sold for US\$2.14-4.17 per ton, and UK allowances (vintage 2002) sold for US\$5.76-9.36 per ton (Rosenzweig 2002).

In the UK government auction of incentive funds for its emissions trading scheme, a total of 34 companies bid successfully in the auction and have taken on emission caps. The clearing price in the auction was £53 (US\$77) per ton of CO<sub>2</sub>e, with an average price of about £16 (US\$23) per ton. However, following the auction, allowances have traded at much lower prices (PointCarbon 2002b). Note that these price levels are not comparable to the price per ton reported in actual trades, or the price per ton that might result in IET. The UK program is a unique program of incentive funding covering a period of five years.

The ultimate price level for carbon emissions is the subject of much debate and analysis. Prices will be dependent on which countries participate in trading, how the trading schemes are structured and the influence of economic and technical trends. A summary of eight modelling studies of the marginal cost of carbon dioxide abatement showed wide variation in estimated costs of abatement with trading. If only Annex B countries participated in trading, the estimated costs ranged from US\$6-36 per ton CO<sub>2</sub>e, with an average estimate of US\$24 per ton, and if trading participation was global, the estimated costs ranged from US\$4-24 per ton CO<sub>2</sub>e, with an average estimate of US\$8 per ton CO<sub>2</sub>e (International Energy Agency 2001). However, these studies were done prior to the U.S. withdrawal from the Kyoto Protocol. Without U.S. participation, prices are expected to be much lower.

## **Simulations**

Several simulations of emissions trading have been performed in order to understand its nature. The major result from the simulations is often the indication of the extent to which abatement costs will be reduced when trading is used. Simulations can either be performed in computer models or as games with participation from various market actors. The results from some of these simulations are reported in (IEA 2001).

Eurelectric has in three rounds performed the Greenhouse gas and Electricity Trading Simulation (GETS) in co-operation with Euronext and PriceWaterhouseCoopers. The first two rounds were game simulations, while the third was a computer simulation. Only utilities participated in GETS1, while major consumers were also invited in GETS2 (Eurelectric 2000). The Swedish District Heating Association participated in GETS2 with the aggregated capacity of all existing CHP plants connected to district heating in Sweden. According to (Larsson 2002), the annual output of power generated was doubled from these CHP plants, when a common reduction of 8 % for carbon dioxide emissions was fulfilled. The additional power generation replaced mainly electricity from coal condensing plants in other countries.

## Resources

The information resources about emissions trading are growing very fast, and consequently the subject presents a moving target. The Internet offers numerous sites with international, governmental, and commercial information about emissions trading.

An accounting system for corporate GHG emissions has been proposed by the World Business Council for Sustainable Development (WBSCD) and the World Resources Institute (World Business Council 2001). This GHG protocol consists of accounting and reporting standards, guidance and calculation tools for companies to apply to their own emissions. The protocol can be found at <http://www.ghgprotocol.org>.

Emissions Trading Handbook: A press release announcing the availability of Spanish and Japanese translations of the Emissions Trading Education Initiative's Emissions Trading Handbook has been posted to the ETEI website <http://www.etei.org/release.html>. This handbook is designed to help practitioners gain a better understanding of how ET markets function. It is also a useful introduction for other stakeholders who are similarly interested

The International Emissions Trading Association is found on [www.ieta.org](http://www.ieta.org)

Other sites with long link-lists to other sites with information about emissions trading are:

[www.gert.org/links/other.htm](http://www.gert.org/links/other.htm)

[www.energistyrelsen.dk/uk/energy\\_reform/emissions\\_trading/index.htm](http://www.energistyrelsen.dk/uk/energy_reform/emissions_trading/index.htm)

[www.kyoto-experts.com/links.asp](http://www.kyoto-experts.com/links.asp)

[www.ieta.org/Library\\_Links/Links\\_Content.htm](http://www.ieta.org/Library_Links/Links_Content.htm)

[www.chicagoclimatex.com](http://www.chicagoclimatex.com)

[www.cleanaircanada.org](http://www.cleanaircanada.org)

[www.pewclimate.org](http://www.pewclimate.org)

[www.prototypecarbonfund.org](http://www.prototypecarbonfund.org)

# Trading Scheme Design Issues

## Introduction

Quantification of DHC/CHP emission reductions, and recognition of those reductions in GHG trading programs, presents a number of analytical and program design issues. Evaluation and discussion of the issues is difficult because the overall legal framework, methodologies and procedures have not yet been developed, with a wide range of possible outcomes for overall trading scheme designs.

The analytical evaluation is further complicated by the fact that “emissions trading” could take place under a cap-and-trade mechanism (under IET or under a domestic trading scheme feeding into IET), or under the project-based mechanisms (JI and CDM). Project-based mechanisms provide significant potential flexibility to deal with many issues related to DHC and CHP, although care must be taken to properly implement the opportunities for flexibility. On the other hand, IET and related domestic schemes present a number of additional trading scheme structural issues.

In this section, relevant characteristics of DHC and CHP are summarized, and six representative DHC/CHP scenarios are described, illustrated and outlined. In addition, the efficiencies and emissions of seven CHP technologies are quantified and compared to conventional alternatives for power and heat generation. These scenarios and the emissions analyses are then used in the discussion of key emission trading program design issues. The UK analysis presented in **Appendix 6** provides further discussion of these issues in the context of the UK trading scheme.

## Characteristics of DHC and CHP

The characteristics of DHC and CHP systems present unique issues relative to meeting emission trading program design objectives. DHC/CHP systems can generate three different forms of energy output (electricity, heating, cooling), resulting in the elimination (or prevention) of emissions from:

- multiple small heating facilities whose GHG impacts will vary depending on the displaced building heating technology, fuel and seasonal efficiency;
- multiple small cooling facilities whose GHG impacts will vary depending on the displaced building cooling technology, energy source, refrigerant type, and seasonal efficiency; and
- power generation sources whose GHG impacts will vary depending on the displaced mix of generating sources.

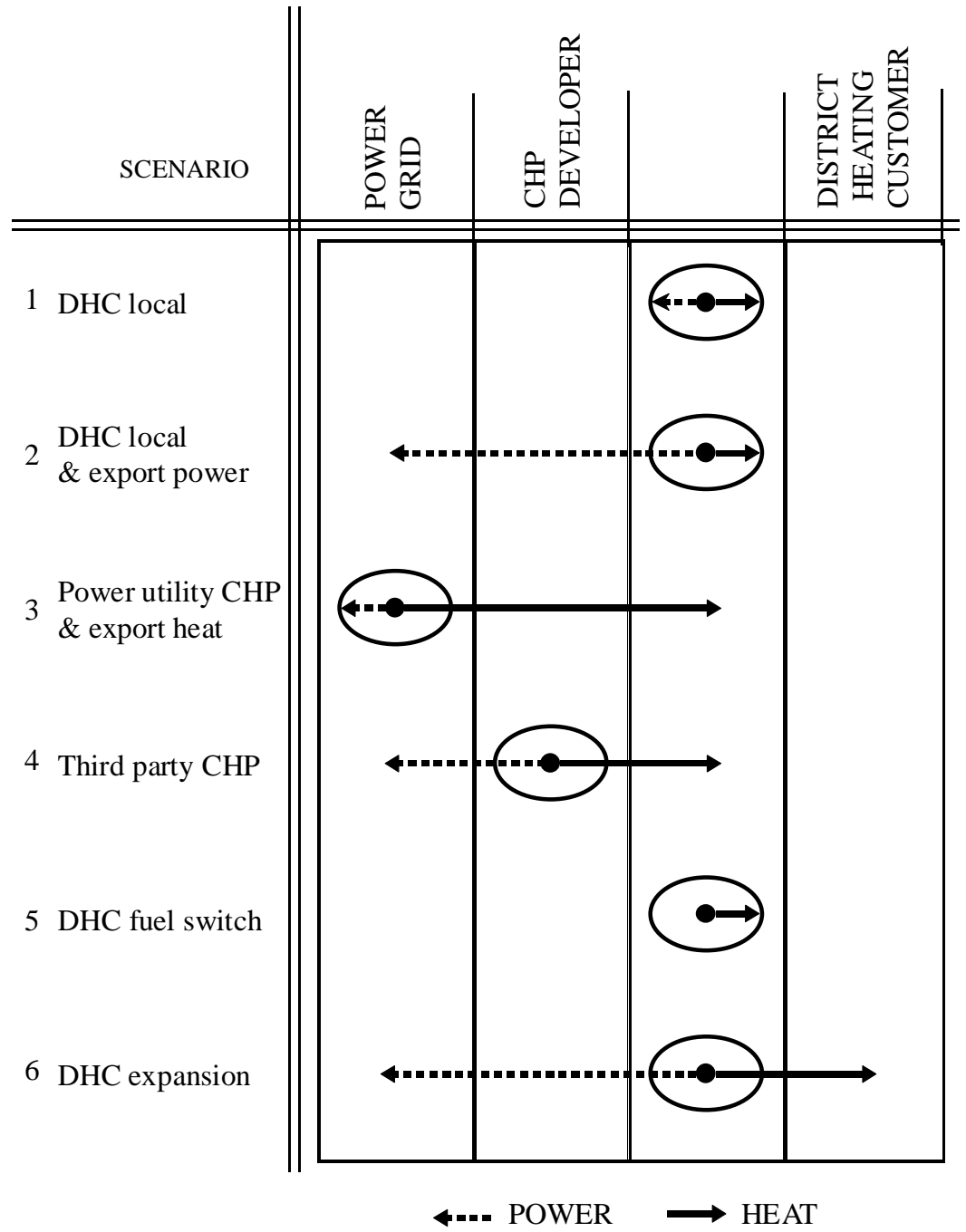
The impact on carbon emissions at of implementation of CHP also depends on the power/heat ratio of CHP, the efficiency of replaced heat-only boilers and fuel switching.

The following analysis and discussion focuses on district heating due to the significant additional complexities presented by district cooling production alternatives and due to the relatively small role played by district cooling globally.

## Analysis of DHC/CHP Scenarios

In order to explore emissions trading program design issues it is useful to delineate basic DHC/CHP situations. **Figure 3** illustrates power and heat energy flows in six DHC/CHP scenarios. These scenarios are not intended to comprehensively cover all possible situations, but are presented to illustrate the potential for crossing boundaries between legal entities or between sectors.

Figure 3. DHC/CHP Scenarios Energy Flow Illustration





Legal entities include:

- Power company
- District heating company or other entity requiring process heat
- Third party CHP developer
- District heating system customer

Sectors include:

- Power sector
- Heat sector
- Buildings sector

The DHC/CHP scenarios can be summarised as follows:

1. DHC local -- A district heating company or other entity which currently uses heat-only boilers and grid electricity installs a CHP system and uses all the CHP heat and electricity on site.
2. DHC local & export power -- A district heating company or other entity which currently uses heat-only boilers and grid electricity installs a CHP system and uses all the heat, but exports some or all of the electricity to the grid.
3. Power utility CHP & export power -- An electric utility installs new CHP or converts an existing power plant to CHP, and uses the electricity for grid supply and sells heat to a district heating company or other entity which currently uses heat-only boilers.
4. Third party CHP -- A CHP developer constructs a new CHP installation and sells the electricity to the grid and the heat to a district heating company or other entity which currently uses heat-only boilers.
5. DHC fuel switch -- A district heating company or other entity which currently uses heat-only boilers switches to a lower carbon fuel.
6. DHC expansion -- A district heating company expands production from an existing CHP plant to supply heat for a new customer, with additional electricity output sold to the grid.

**Figure 4** is a matrix that further describes these scenarios relative to energy flows, boundary crossing and emissions.

Figure 4. DHC/CHP Energy and Emissions Matrix

Energy flows across boundaries before Action	SCENARIO					
	1. DHC local	2. DHC local & export power	3. Power utility CHP & export power	4. Third party CHP	5. DHC fuel switch	6. DHC expansion
Entity's source of electricity	Grid	Grid	NA	NA	NA	NA
Entity's source of heat	Heat-only boilers	Heat-only boilers	Heat-only boilers	Heat-only boilers	Heat-only boilers	CHP
New Customer's source of heat	NA	NA	NA	NA	NA	Boiler or other equipment
<b>Action</b>						
Summary of Action	DH system or other Entity installs CHP	DH system or other Entity installs CHP	Power company installs CHP and sells heat to Entity	CHP developer installs CHP, and sells power to grid and heat to DH system or other Entity	Entity switches from high carbon fuel to low-carbon fuel	DH system supplies new Customer with CHP heat, and expanding operation of existing CHP plant
Use of electricity from CHP	All electricity used on Entity site	All or some of electricity sold to grid	Used by power company to supply grid	Sold to grid	NA	Increased generation goes to grid
Use of heat from CHP	All heat used to offset other on-site heat production	All heat used to offset other on-site heat production	Sold to DH company or industrial user	Sold to Entity	NA	Supply new Customer
<b>Impact on energy flows across boundaries</b>						
Change in Entity use of fuel for heat-only boilers	Decrease	Decrease	Decrease	Decrease	Likely decrease ***	No change
Change in overall Entity use of fuel	Likely increase *	Likely increase *	Decrease	Decrease	Likely decrease ***	Increase
Change in flow of electricity from Entity to grid	NA	Increase	No change	NA	NA	Increase
Change in Entity use of grid power	Decrease	Decrease or no change	No change	NA	NA	No change
Change in flow of power from CHP Developer to grid	NA	NA	NA	Increase	NA	NA
Change in grid use of fuel	Decrease	Decrease	Increase	Decrease	NA	Decrease
Change in Customer use of DH	NA	NA	NA	NA	NA	Increase
<b>Impact on energy production</b>						
Heat production at Entity site	No change	No change	Decrease	Decrease	No change	Increase
Electricity production at Entity site	Increase	Increase	No change	NA	NA	Increase
Electricity production by grid capacity	Decrease	Decrease	Likely increase **	Decrease	NA	Decrease
Heat production at Developer site	NA	NA	NA	Increase	NA	NA
Electricity production at Developer site	NA	NA	NA	Increase	NA	NA
Heating production at Customer site	NA	NA	NA	NA	NA	Decrease
<b>Impact on emissions</b>						
Change in Entity emissions from heat-only boilers	Decrease	Decrease	Decrease	Decrease	Decrease	No change
Change in Entity overall emissions	Likely increase *	Likely increase *	Decrease	Decrease	Decrease	Increase
Change in emissions from grid capacity	Decrease	Decrease	Increase or decrease +	Decrease	NA	Decrease
Change in Developer emissions	NA	NA	NA	Increase	NA	NA
Change in Customer emissions	NA	NA	NA	NA	NA	Decrease

**NOTES**

NA means this is not applicable to this scenario.

\* Increase or decrease depending on size and power/heat ratio of CHP, efficiency of replaced heat-only boilers and fuel-switching.

\*\* Increase if installing new CHP plant in addition to other grid capacity, decrease if converting existing steam cycle power plant to CHP.

\*\*\* Likely decrease resulting from higher efficiency of new equipment.

+ Depending on fuel for the CHP plant compared to fuel in displaced grid capacity.

In addition to the above-described DHC/CHP scenarios, it is also useful to characterise representative CHP technologies for this analysis of emissions trading issues. For this purpose, profiles of seven CHP technologies were prepared, and a variety of analyses were developed, as summarized in **Appendix 7**. The CHP technologies included:

- Small (5.2 MWe) gas-fired reciprocating engine
- Small (10.7 MWe) simple cycle gas turbine
- Medium (27.8 MWe) combined cycle gas turbine
- Large (102.8 MWe) combined cycle gas turbine
- Medium (30.4 MWe) coal-fired steam turbine
- Large (93.6 MWe) coal-fired steam turbine
- Medium (30.4 MWe) biomass-fired steam turbine

The CHP technologies were compared to conventional alternatives for generating the same quantities of heat and power. Heat was assumed to be produced with a 85% efficient (LHV) heat-only boiler, burning gas for comparison with gas-fired CHP and coal for comparison with coal-fired CHP. Power generation emissions were calculated three ways, as further described in **Appendix 7**:

- New gas turbine condensing combined cycle power plant (assumed 54% LHV efficiency including power transmission and distribution losses)
- Value used in the UK emissions trading scheme
- Emissions of the marginal displaced capacity in the UK

Additional background on the UK values can be found in **Appendix 6**.

**Figure 5** summarises the resulting comparison of CHP emissions to conventional alternatives. All of the gas-fired CHP technologies show significant net reductions in emissions, even with the conservative comparison with conventional power generation assumed to be a highly efficient combined cycle gas turbine. The coal-fired CHP options show smaller percentage reductions compared to conventional alternatives, ranging from a zero impact, for the smaller coal CHP facility compared to new combined cycle power generation, to about 25% reduction for the larger coal CHP compared to marginal UK displaced capacity. Biomass carbon emissions are assumed to be zero, consistent with international guidelines (IPCC 1996). This zero factor takes into account the offsetting GHG reduction (CO<sub>2</sub> consumption during biomass growth and/or avoidance of methane and CO<sub>2</sub> generation during biomass degradation which would otherwise take place for waste biomass). This is consistent with the proposed EU trading directive (European Commission 2001 c).

Carbon dioxide reduction credits can have a potentially significant economic value. The Net Present Value (NPV) of a 20-year stream of emission credits (5% discount rate) is illustrated in **Figures 6, 7 and 8** as a percentage of the estimated capital cost of each representative CHP technology. **Figure 6** represents a conservative assumption of US\$5 per ton CO<sub>2</sub>, which is in the middle of the range of values of the few trades that have taken place to date for vintage years 2008-2012, and is also equal to the value of the penalty in the currently operating Danish trading for excess emissions above the level for which the emission source holds allowances. **Figures 7 and 8** reflect values of US\$15 and US\$30 per ton, respectively. This range of values may be more consistent with the long-term value of carbon. **Figure 9** summarises in table format the NPV results presented graphically in **Figures 6, 7 and 8**.

Installation of CHP will increase GHG emissions at the plant site in comparison with production of heat using heat-only boilers. The percentage increase in on-site emissions is illustrated in **Figure 10**. Emissions for gas-fired CHP are compared to emissions for gas-fired heat-only boilers, and emissions for coal or biomass CHP are compared to coal-fired heat-only boilers. The level of increase is related to the power:heat ratio. The higher this ratio, the larger the percentage increase in on-site emissions, because now fuel is being consumed to generate power as well as heat. These calculations highlight the importance of gaining credit for the emission reductions that occur elsewhere (in the power grid or in building boilers).

Additional analysis of comparative emissions in a broader context is presented in **Appendix 8**. The analyses presented in **Appendices 6 and 8** are based on slightly different assumptions and methodologies, but give compatible results. One difference is that in **Appendix 6** all comparisons are made assuming all heat-only boilers are fired with gas.

Figure 5. CO<sub>2</sub> emission reductions with various CHP technologies

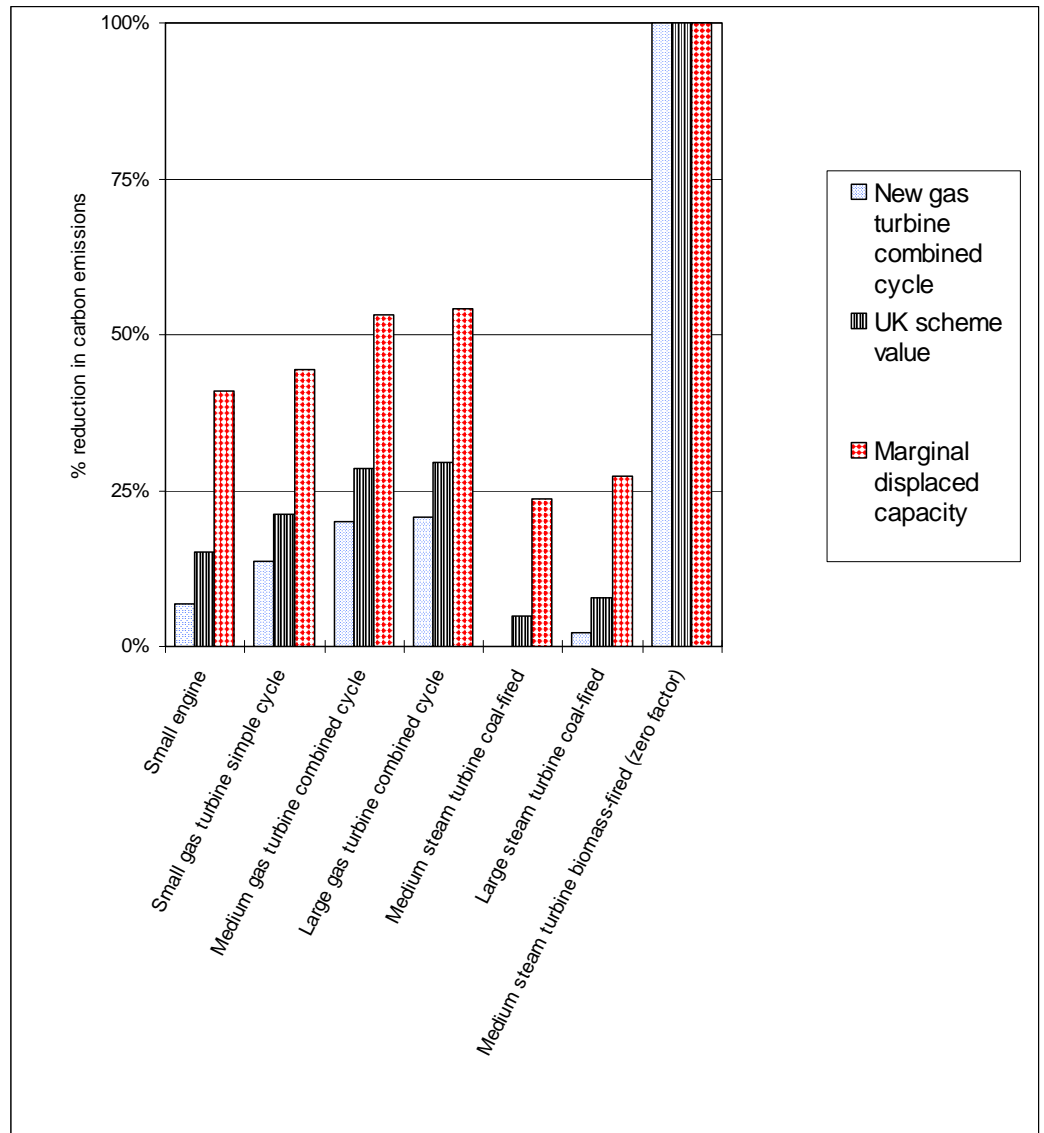


Figure 6. NPV of CO<sub>2</sub> reductions as percentage of CHP capital cost (US\$5/ton CO<sub>2</sub>)

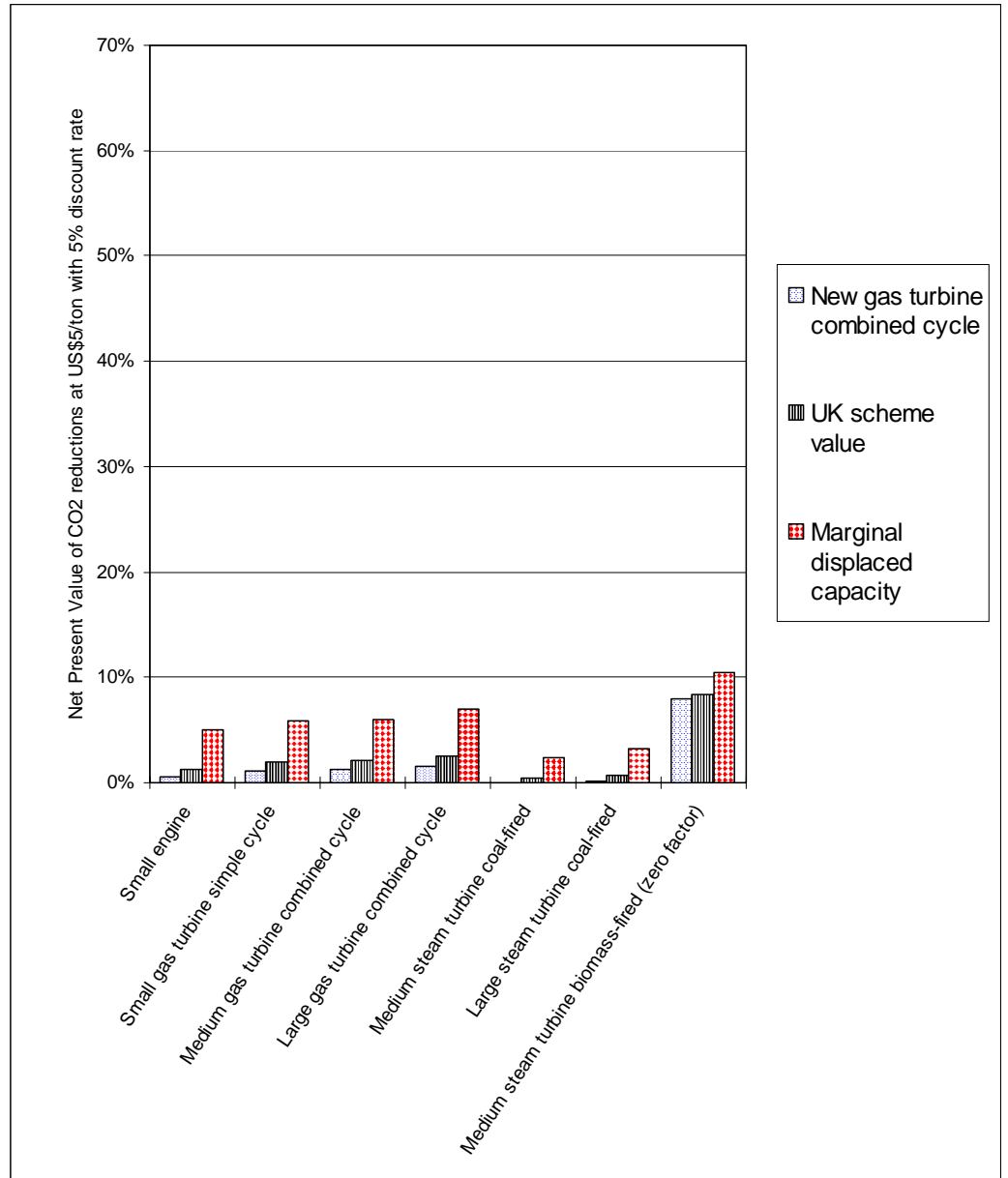


Figure 7. NPV of CO<sub>2</sub> reductions as percentage of CHP capital cost (US\$15/ton CO<sub>2</sub>)

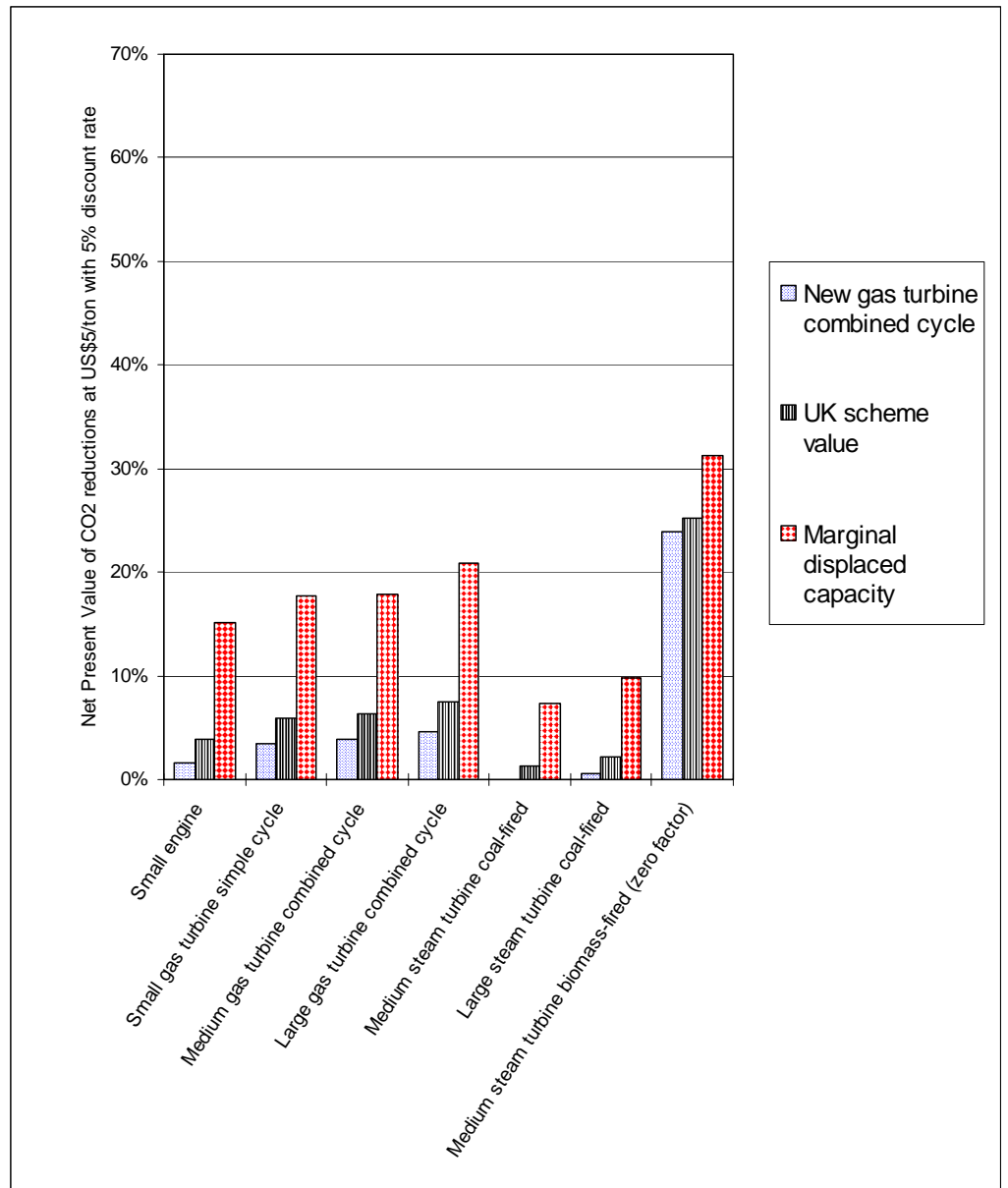


Figure 8. NPV of CO<sub>2</sub> reductions as percentage of CHP capital cost (US\$30/ton CO<sub>2</sub>)

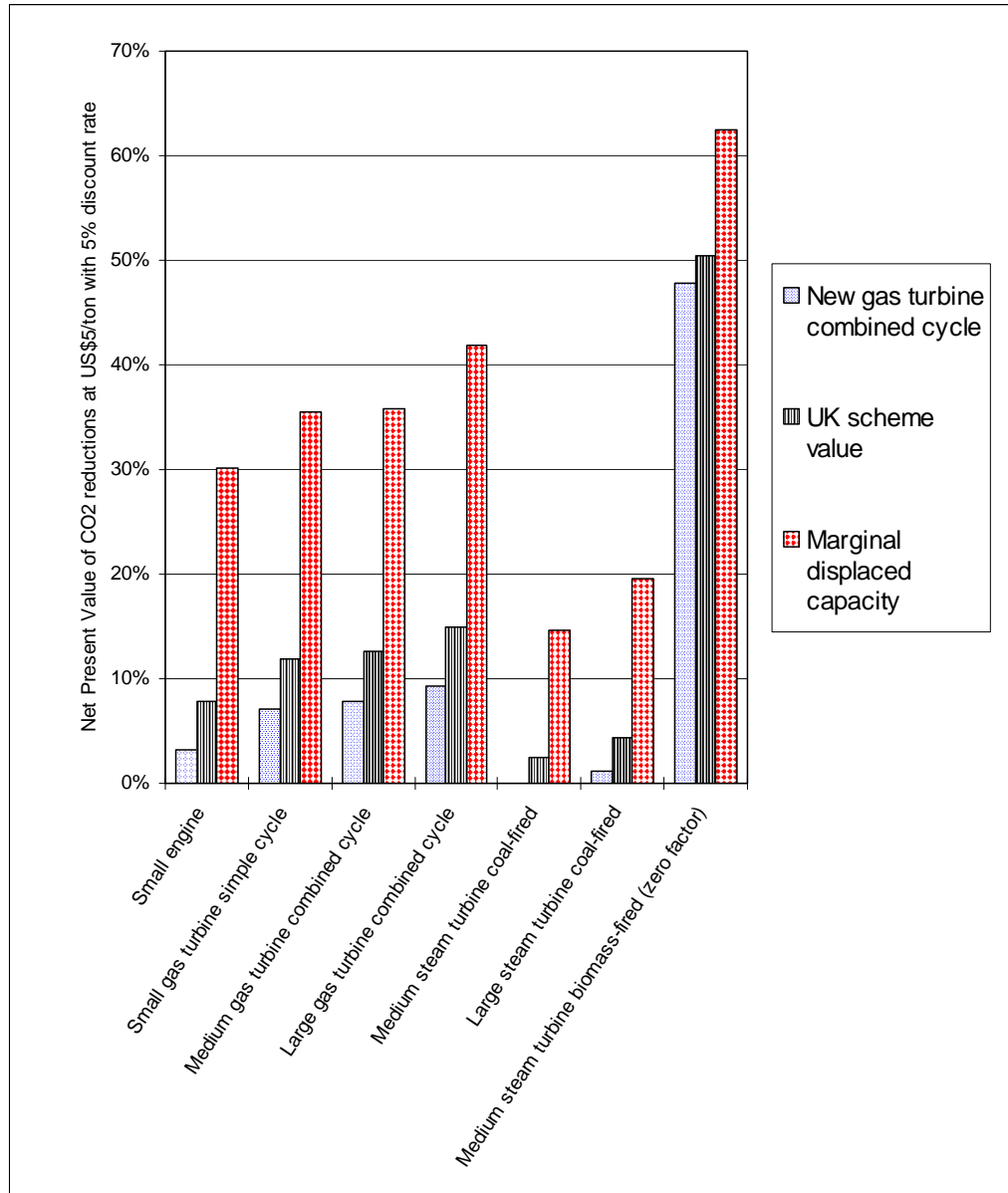
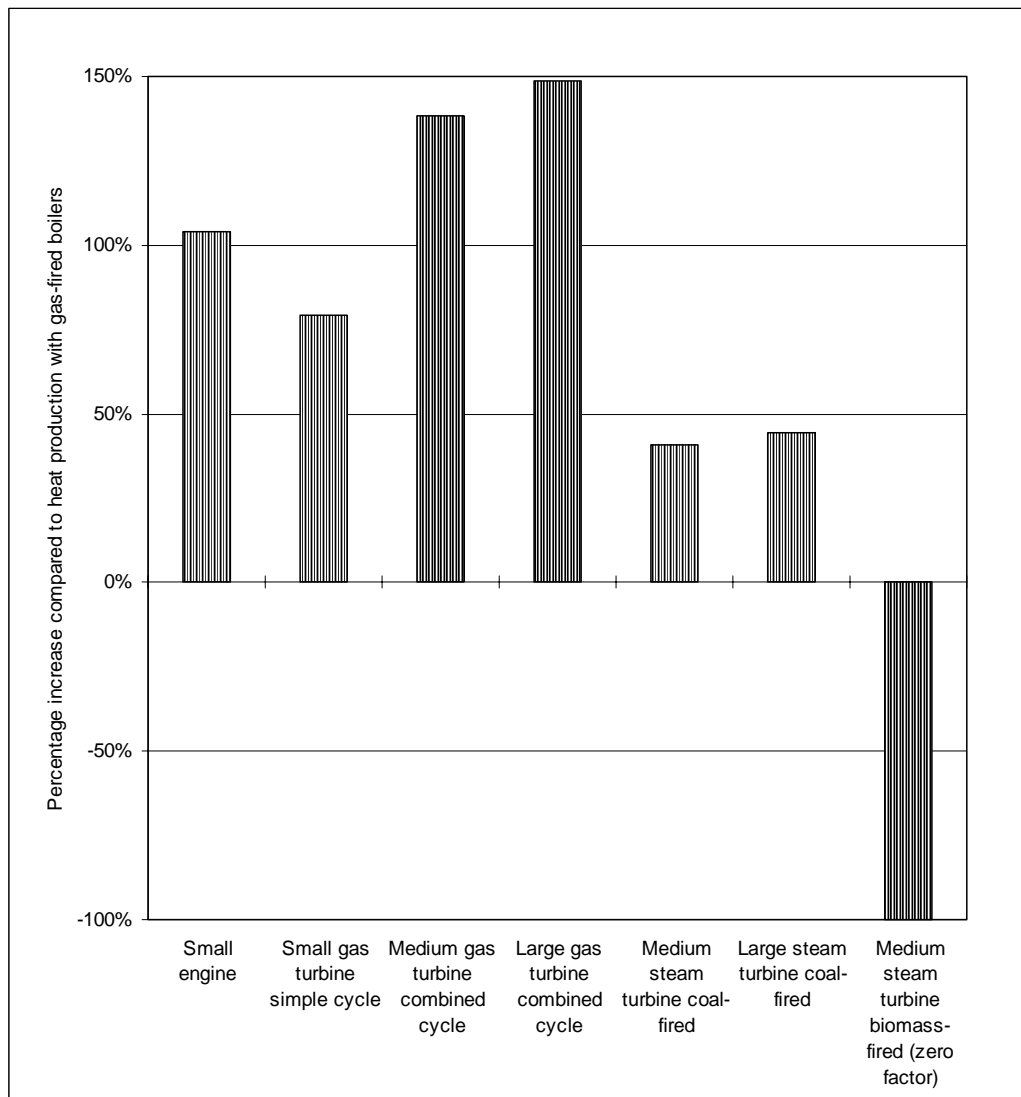


Figure 9. Summary table of value of CO<sub>2</sub> reductions as percentage of CHP capital cost

	Small engine	Small gas turbine simple cycle	Medium gas turbine combined cycle	Large gas turbine combined cycle	Medium steam turbine coal-fired	Large steam turbine coal-fired	Medium steam turbine biomass-fired	Medium steam turbine biomass-fired (zero factor)
<b>US\$5/ton of carbon dioxide</b>								
New gas turbine combined cycle	0.5%	1.2%	1.3%	1.6%	0.0%	0.2%	-1.0%	8.0%
UK scheme value	1.3%	2.0%	2.1%	2.5%	0.4%	0.7%	-0.6%	8.4%
Marginal displaced capacity	5.0%	5.9%	6.0%	7.0%	2.4%	3.3%	1.5%	10.4%
<b>US\$15/ton of carbon dioxide</b>								
New gas turbine combined cycle	1.6%	3.5%	3.9%	4.7%	0.0%	0.6%	-3.0%	23.9%
UK scheme value	3.9%	6.0%	6.3%	7.4%	1.2%	2.2%	-1.7%	25.2%
Marginal displaced capacity	15.1%	17.8%	17.9%	20.9%	7.3%	9.8%	4.4%	31.3%
<b>US\$30/ton of carbon dioxide</b>								
New gas turbine combined cycle	3.1%	7.0%	7.9%	9.3%	0.0%	1.2%	-5.9%	47.9%
UK scheme value	7.8%	11.9%	12.6%	14.9%	2.5%	4.3%	-3.4%	50.4%
Marginal displaced capacity	30.2%	35.5%	35.8%	41.9%	14.6%	19.5%	8.7%	62.5%



**Figure 10.** Percentage CO<sub>2</sub> emissions increase at DHC plant with CHP compared to heat-only boilers



## Structural Issues

### *Allowance allocation*

As described above under “Emission Trading Programs,” entities operating within a cap-and-trade program must surrender allowances equal to their actual emissions for a given year. The total quantity of allowances is based on the country’s GHG reduction commitment and how that country allocates the burden between the trading sector and non-trading sectors (in which GHG reductions are accomplished through other policies and measures).

Within the trading sector, allowances may be allocated a number of ways. The allocation principle is hotly debated and will be very important for DHC and CHP. Each method has its own advantages and disadvantages:

- Advocates of an allocation system based on past emissions (“grandfathering”) argue that it is important to minimize the economic disruptions caused by a transition to emission allowances. However, from a longer-term policy perspective, grandfathering is not an appropriate allocation approach because it will tend to reward inefficient producers and penalize efficient ones. In addition, it creates difficulties relative to new entrants who, because they have no historical emissions, would have the added burden of purchasing allowances on the market. A solution sometimes proposed in a grandfathered system is a “set-aside” of allowances for new entrants.
- It is possible to implement a modified form of grandfathering based on benchmarking, which establishes an amount of allowances per unit of output for each sector. For CHP plants the total useful energy output will include both electricity and thermal energy. With the benchmarking approach, a CHP plant, for example, should be allocated allowances for both its heat and power production. The allocations can be modified as outputs change, and new entrants can be accommodated. An output-based approach has been developed by the U.S. Environmental Protection Agency, but not yet implemented, for nitrogen oxides trading.
- With an allocation system based on auction, fewer allowances will be needed for DHC and CHP compared to competitors using carbon-rich technologies. This is a potentially appropriate approach for the long term, particularly if the funds collected are recycled in a way that rewards more efficient plants.

There is widespread recognition of the benefits of auctioning relative to maximizing economic efficiency, but there is also great appreciation of the political barriers to auctioning due to economic competitiveness issues. Thus, it is likely that some form of grandfathering, possibly including benchmarking, will be used in early implementation of emissions trading, with a potential transition to auctioning.

Grandfathering based on benchmarking is the best approach for initiating a trading system. It will be necessary to adjust the allocations in future compliance periods to reflect the mix of plants in operation. The most appropriate allocation system would be based on emissions per unit of product output. In the energy sector, allowances should be allocated based on total useful energy output, including both power and heat from CHP.

In the EU, the principles for allocation of allowances should be the subject of agreement at the European Community level. The uniformity of allocation approach is not significant for DHC (which is not traded across borders) but it is important for CHP. A common allocation approach will ensure fair competition for CHP plants across borders.

It is also important that the allocation process rewards early action to reduce carbon emissions, or at least does not penalize early action.

## *Boundaries*

When energy from DHC and/or CHP flows from one legal entity or sector to another, there is the potential that the emissions trading scheme will not recognize or credit the related emission reduction and create competitive distortions. Boundary issues arise in several contexts:

- whether or not the sector is included in the trading scheme; and
- whether an entity initiating and GHG reduction action has ownership and/or control over emission reductions resulting from the action.

Emission trading programs, particularly in the early years, will most likely be applied to major emission sectors and sources. The power sector will certainly be included in emission trading systems in effect in 2008 and thereafter (as opposed to early voluntary programs such as the UK program described in **Appendix 6**), as will be the heat sector within the EU. The EU trading scheme, when it starts in 2005, will include emission sources covered by the IPPC Directive as well as power and heat generators with a rated input capacity of 20-50 MW. Notably, the buildings sector is not envisioned for inclusion in the EU scheme or any “downstream” domestic trading scheme (i.e., requiring surrender of allowances by the entity actually emitting GHG, as opposed to “upstream” systems which require allowance surrender by producers or distributors of energy).

If a DHC company or other entity (e.g. an industrial plant) installs CHP to provide on-site power and heat (Scenario 1), the increased on-site emissions from the CHP are partially offset by a reduction in emissions due to reduced operation of heat-only boilers. Although the CHP power output does not cross the boundary into the power grid, this CHP power output does decrease the need to purchase power from the grid, thus reducing “indirect emissions” related to generating power to supply the grid. In a domestic cap-and-trade scheme, the DHC company will have to surrender additional carbon allowances if it installs CHP. A key issue is whether the allowance allocation system will provide additional allowances in recognition of the total energy output of the CHP project. The CHP project should receive allocations for both the power and heat output. In project-based trading mechanisms, it is important that a trading scheme fully credit the CHP project for the avoided emissions for both heat and power generation.

Similar issues arise if, instead of using all of the CHP power output on site, the CHP facility sells excess power to the grid (Scenario 2). In this case, the sectoral and entity boundaries are more clearly crossed, although the net effect is the same as in Scenario 1: reduced power generation (with related emission reductions) by alternative generation capacity feeding the grid.

A power company might construct a CHP facility (or convert an existing power plant to CHP) and sell heat to a DHC company or other entity requiring heat (Scenario 3). In this case, the heat crosses the boundary, but the requirement to surrender allowances remains with the power company. Lack of recognition of the offset heat sector emissions in allowance allocation will act as a disincentive to initiating CHP in the power sector.

CHP facilities are increasingly constructed by CHP developers who then sell the power to the grid and heat to a DHC company or other entity (Scenario 4). In this case, the CHP facility is owned by a legal entity that is separate from the thermal user or the power company, and may be considered outside both the power sector and the heat sector. Although the CHP facility will likely be constructed on or near the site of the thermal user, the ownership of the CHP facility will be in a separate legal entity. In cap-and-trade schemes, implementation of CHP by a CHP developer will be inhibited if allowance allocation is grandfathered, thus requiring the CHP developer to acquire allowances on the market. In project-based trading schemes, the separation in ownership may inhibit recognition of emission reduction.

Another potential scenario is fuel substitution, for example a DHC company installing a new gas-fired boiler to replace an existing coal boiler (Scenario 5). In this case, no entity or sectoral boundaries are crossed, presenting no discernable emission trading scheme design issues.

Finally, it is important to consider the boundary between the DHC entity and sector and the customer in the buildings sector. For example, a DHC company may increase operation of an existing CHP facility in order to serve new customers (Scenario 6). In this case, the increased CHP heat production crossed over to the buildings sector, and the increased CHP power is sold to the grid (or it could offset power which would otherwise be purchased from the grid). In addition

to the problems related to crossing the power/heat sectoral boundary, in this scenario another even more difficult boundary is crossed – into the buildings sector, which will not be included in “downstream” cap-and-trade schemes.

It is important that equivalently stringent GHG emission constraints be placed on building heating systems through other policies and measures. Alternatively, cap-and-trade programs should credit a DHC system for its impact on total emissions in the allocation of allowances or in the determination of the quantity of allowances required to be surrendered by a DHC system. Quantification and verifications of offset building boiler emissions present potential problems relative to data availability and quality, and relatively high transaction costs for verification.

Project-based trading mechanisms provide an opportunity to credit the total emissions benefits of a DHC/CHP project, but it is important that such programs credit the avoided power production emissions based on marginal capacity on the power side and the avoided heat production emissions even if it is in the buildings sector.

#### *Avoided Power Generation Emissions*

Quantification of emission reductions resulting from reduced demand on the power grid (often called “indirect emission reductions”) is an important issue, not only for CHP but also for demand-side management and renewable power generation technologies. In an increasingly complex, dynamic and market-based power supply system, it is increasingly difficult to determine the emissions implications of reduced power demand on the grid plant mix. As older, less efficient grid generation is replaced by new, more efficient capacity, the emissions avoided through reduction in grid power requirements or export of CHP power to the grid is reduced. Establishing an appropriate value for indirect emission reductions is a key issue for project-based trading schemes.

Three alternative assumptions regarding offset grid emission were calculated in the analysis summarized in **Figures 5, 6, 7 and 8**: large new gas-fired combined cycle condensing power plants, marginal capacity in the grid mix, and the value used in the UK trading scheme.

In the near term, it is most appropriate to calculate indirect emission reductions based on the emission characteristics of the marginal capacity in a supply mix. As discussed in **Appendix 6**, this value was determined to be 0.21 kg C (0.77 kg CO<sub>2</sub>) per kWh electricity in the UK. This value would be comparable to a large coal condensing plant if it had a conversion efficiency of 43% (LHV).

On the other hand, in the long term, it has been argued that large gas-fired combined cycle condensing power plants will become the marginal plant, and that emission comparisons should be based on this. As shown in **Appendix 7**, this value is estimated to be 0.10 kg C (0.37 kg CO<sub>2</sub>) per kWh electricity assuming a conversion efficiency of 54%. This is close to the value adopted for the UK emission trading scheme as described in **Appendix 6**. It is important to note that gas turbine combined cycle cannot be the total future for power generation, for reasons relating to production capacity, transmission and distribution constraints, and for energy security reasons. It is essential for energy security that we not “put all our eggs in one basket.” Basing emission trading scheme values on gas turbine combined cycle plants is not good public policy.

To truly reflect the emission reduction benefits of CHP and other technologies that affect the grid, it is important that the value used reflects the marginal capacity of the grid during the time period in which the facility operates. With a benchmarking allocation system, this value can be updated as the grid mix evolves.

# Conclusions and Recommendations

## Conclusions

### *Benefits of DHC and CHP*

DHC and CHP provide a variety of opportunities to reduce GHG emissions, reduce air pollution and increase energy security. The fundamental idea of DHC is to use local fuel or energy resources, that would otherwise be wasted, in order to satisfy local customer thermal energy requirements. Examples of local energy resources are heat from combined heat and power (CHP) plants, refuse incineration plants, waste heat from industrial processes, natural geothermal heat sources, wood waste, and cold sea or lake water.

The ability of DHC networks to use local heat sources is of great national and international value in achieving reductions in emissions of air pollution and GHG such as carbon dioxide (CO<sub>2</sub>). DHC and CHP also enhance energy security in a variety of ways, including:

- increasing fuel supply reliability by using indigenous fuels like biomass or waste;
- strengthening power grid reliability by generating power near load centres;
- reducing power demand by supplying heating or cooling energy through DHC systems rather than the power grid; and
- shifting power demand to off-peak periods through thermal energy storage.

In the short term, the combination of DHC and CHP is a carbon-lean technology that will gain strong initial competitive strength from emissions trading systems if the trading systems are designed to recognize and reward the total emission reductions.

The contribution from DHC and CHP can be significant for fulfilling the Kyoto commitment for 2008-2012, since the marginal production in the current international electricity market in Europe has high carbon dioxide emissions, due to use of coal as fuel and the low efficiencies used.

When the marginal production in the international electricity market reduces its emissions and reaches higher efficiencies, conventional district heating using CHP plants with fossil fuels will lose competitive strength. However, this is not a unique situation for DHC/CHP; it will apply to all carbon-lean technologies, since the future competition will not come from carbon-rich technologies, but from other carbon-lean technologies.

Current carbon dioxide emissions avoided due to the use of DHC /CHP is significant and is about half of the magnitude of carbon dioxide reduction presumed in the Kyoto protocol.

For the future, DHC/CHP can make significant additional contributions to global carbon emission reductions by:

- increasing the market penetration of district heat generation through new systems and expansion of existing systems;
- increasing the share of CHP in existing district heat generation, since only 48% is currently produced from CHP; and
- fuel substitution in existing DHC/CHP plants, since coal constitutes 38% of fuel supplied.

### *Barriers*

The environmental and energy security benefits of DHC and CHP are not currently priced in the marketplace. Unfettered market forces tend to result in solutions that may be shorter-term than is optimum for society and discriminate against capital-intensive technologies such as DHC and CHP.

When an emissions trading scheme is fully operational this will be an important step toward internalisation of environmental externalities. However, such a system will not be fully functioning until 2008 or later.

Without action to address barriers, the development of DHC and CHP potential will be seriously hampered by the effects of energy market liberalisation.

With energy market liberalisation the focus on short-run economics and financial performance works against implementation of capital-intensive sustainable technologies such as DHC and CHP.

GHG trading will not address the other environmental benefits of CHP resulting from reductions in emissions of air pollution, nor will it provide recognition of the energy security benefits.

In some countries the present and suggested energy tax systems neglect the full environmental benefits of CHP. For example, in Finland and Sweden heat from CHP plants is taxed as if the heat would have been produced in heat-only boilers. This prevents the CHP industry from fulfilling its potential for improving the environment and energy security.

There are a number of areas related to interaction of CHP facilities with the power grid where treatment of CHP facilities can be improved to, at the very least provide a level playing field, and in some areas provide an appropriate means of recognizing the environmental and energy security benefits of DHC/CHP. Many of these issues will disappear when the transition to a fully functioning liberalised market is completed. However, until that transition is completed, a number of issues remain problematic in many markets, including:

- Access to transmission and distribution systems;
- Technical standards for interconnection of CHP facilities to the grid;
- Bearing of costs relating to grid connection and grid reinforcement;
- Tariffs for sale of surplus power to the grid;
- Tariffs for use of grid to transport power to buyers; and
- Tariffs for purchase of back-up and top-up power.

The UK Quality Assurance program provides a good model for development of an EU framework, and provides a reasonable approach to definition of a CHP quality threshold to qualify for special treatment (e.g., externality payments in grid supply power purchase, or for tradeable CHP certificates), although a looser definition should be adopted for purposes related to reporting CHP statistics.

#### *Emissions Trading Program Design*

In the EU, the uniformity of the national approaches taken to allowance allocation is not significant for DHC (which is not traded across borders) but it is important for CHP.

When energy from DHC and/or CHP flows from one legal entity or sector to another, there is the potential that the emissions trading scheme will not recognize or credit the related emission reduction. Boundary issues arise in several contexts:

- whether or not the sector is included in the trading scheme; and
- whether an entity initiating and GHG reduction action has ownership and/or control over emission reductions resulting from the action.

Without some mechanism for crediting offset building boiler emissions, emissions trading will place DHC at a disadvantage unless strong policies and measures applied to the buildings sector.

The value for crediting projects for avoided emissions in the power grid (“indirect emission reductions”) is an important issue for CHP relative to project-based trading schemes as well as allowance allocation in cap-and-trade schemes.

Emission trading schemes will constrain CHP without a means of crediting CHP projects developed by third party CHP developers (who then sell the power to the grid and heat to a DHC company or other entity).

## Recommendations

### *Policy Context*

As policy initiatives, such as the European Union's CHP Directive, the UK CHP initiative and the US CHP Challenge, are developed, it is essential that these initiatives include strong and effective measures that address barriers to implementation of DHC.

Steps should be taken now to internalise the environmental and energy security benefits of DHC and CHP. This is important in order to:

- mitigate the environmentally negative impacts of energy market liberalisation;
- internalise in the marketplace the GHG reduction benefits of DHC/CHP in advance of a fully functioning GHG emissions trading scheme; and
- internalise air pollution and energy security benefits of DHC/CHP.

### *CHP Directive*

The EU CHP Directive should establish CHP implementation targets for each Member State that recognizes the current contribution as well as future potential of CHP. The targets should be binding, with flexibility introduced through a system of tradeable certificates. The program for defining and certifying CHP must be consistent but provide flexibility for recognition of different types of CHP.

The CHP Directive should require Member States to ensure CHP facilities access, under transparent and non-discriminatory terms, to the grid.

- A model interconnection standard would be a useful step. Technical standards and approval processes for interconnection should not be the burden they often are today.
- Limits should be established for grid connection cost per MegaWatt such that costs above this threshold are borne by the grid rather than the individual CHP facility. This would provide some recognition of the grid benefits of smaller CHP plants that supply power to the grid and/or reduce grid power demand but for whom the fixed costs of interconnection are a significant burden. A simple mechanism such as this is preferable to a complex, case-specific analysis of grid constraints.
- The EU should monitor and report on progress toward fair and non-discriminatory interconnection guidelines on a country by country basis, and highlight findings regarding anti-competitive practices that restrict the implementation of CHP.

The CHP Directive should encourage energy and CO<sub>2</sub> tax schemes that at the very least do not discriminate against CHP, and preferably would provide a positive incentive for CHP. Heat from CHP plants should not be taxed as if the heat would have been produced in heat-only boilers.

### *Emission Trading Program Design*

The heat and power sectors should be included in national trading schemes, with facility size thresholds set to include a substantial majority of capacity.

Grandfathering based on benchmarking is the best allocation approach for initiating a trading system. It will be necessary to adjust the allocations in future compliance periods to reflect the mix of plants in operation. The most appropriate allocation system would be based on emissions per unit of product output. In the energy sector, allowances should be allocated based on total useful energy output, including both power and heat from CHP.

In the EU, the principles for allocation of allowances should be the subject of agreement at the European Community level. A common allocation approach will ensure fair competition for CHP plants across borders.

It is important that equivalently stringent GHG emission constraints be placed on building heating systems through other policies and measures. Alternatively, the emissions trading program should credit a DHC system for its impact on total emissions in the allocation of allowances or in the determination of the quantity of allowances required to be surrendered by a DHC system.

Allowance allocation should recognise the total GHG reduction benefits of CHP, with a CHP project receiving allocations from both the power sector allocation and the heat sector allocations.

Allowance allocations should recognize the total emission reduction benefits of CHP even if the legal entity implementing CHP is separate from the entities purchasing the CHP power and heat output.

In allowance allocation for cap-and-trade schemes, and in project-based trading mechanisms, the value used for offset grid emissions (indirect emission reductions) should reflect the marginal capacity of the grid during the time period in which the facility operates. With a benchmarking allocation system, this value can be updated as the grid mix evolves. Indirect emission reduction calculations should not be based on new gas turbine combined cycle condensing plants.

Project-based trading mechanisms provide an opportunity to credit the total emissions benefits of a DHC/CHP project, but it is important that such programs credit the avoided power production emissions based on marginal capacity on the power side and the avoided heat production emissions even if it is in the buildings sector.

The UK QA program provides a reasonable initial framework for addressing the different types and sizes of CHP for the purpose of emissions trading. However, additional provisions are needed to quantify additional benefits of DHC, for example:

- reduction in power demand and energy due to elimination of electric heating in individual buildings;
- reduction in power demand and energy due to substitution of CHP-heat-driven cooling for electric cooling; and
- reduction in power demand due to implementation of thermal energy storage in DHC systems.



# References

- AGFW (2000), *Pluralistische Wärmeversorgung, Strategien und Technologien einer pluralistischen Fern- und Nahwärmeversorgung in einem liberalisierten Energiemarkt unter besonderer Berücksichtigung der Kraft-Wärme-Kopplung und regenerativer Energien*. Kurzfassung der Vorstudie, Frankfurt March 6, 2000. Available at [www.agfw.de](http://www.agfw.de).
- AGFW (2001a), *Pluralistische Wärmeversorgung, Strategien und Technologien einer pluralistischen Fern- und Nahwärmeversorgung in einem liberalisierten Energiemarkt unter besonderer Berücksichtigung der Kraft-Wärme-Kopplung und regenerativer Energien*. Kurzfassung der 1. Band:: Grundlagen der Kraft-Wärme-Kopplung, Zertifizierungsverfahren und Fördermodelle, Frankfurt, March 2001. Available at [www.agfw.de](http://www.agfw.de).
- AGFW (2001b), *Zertifizierung von KWK-anlagen, Ermittlung des KWK-stromes*, Arbeitsblatt FW308. Frankfurt, August 2001. Available at [www.agfw.de](http://www.agfw.de).
- Carboncredits.nl (2002). Web site for Carboncredits program [www.carboncredits.nl](http://www.carboncredits.nl) accessed May 2002.
- Cogen Europe (1998), *Emissions trading and joint implementation – The implications for cogeneration*. Brussels, May 1998.
- Eurelectric (2000), *GETS2 report*. In co-operation with Euronext and PriceWaterhouseCoopers. Brussels, November 6, 2000.
- Euroheat & Power (2001), *CO<sub>2</sub> reductions by Combined Heat and Power in the European Union*. Brussels 2001.
- European Commission (1996), *Council Directive 96/61/EC concerning integrated pollution prevention and control*, OJ L 257, October 10, 1996.
- European Commission (1997), *A Community strategy to promote combined heat and power and to dismantle barriers to its development*, Com(1997)514. Brussels Oct 15, 1997.
- European Commission (2000a), *Green Paper on Greenhouse Gas Emissions Trading within the European Union*, COM (2000) 87. Brussels March 8, 2000.
- European Commission (2000b), *Action plan to improve energy efficiency in the European Community*. Com(2000)247, Brussels April 26, 2000.
- European Commission (2001a), *European Climate Change Program, Long report*. Brussels, June 2001. Available at [www.europa.eu.int/comm/environment/climat/eccp.htm](http://www.europa.eu.int/comm/environment/climat/eccp.htm)
- European Commission (2001b), *Communication on the implementation of the first phase of the European Climate Change Program*, Com(2001)580. Brussels Oct 23, 2001.
- European Commission (2001c), *Proposal for a Directive of the European Parliament and of the Council establishing a framework for greenhouse gas emissions trading within the European Community and amending Council Directive 96/61/EC*, Com(2001)581. Brussels Oct 23, 2001.
- European Commission (2001d), *Background document: Legislative action to Promote Combined Heat and Power (CHP)*, DG TREN, November 5, 2001.
- Eurostat (2001), *Combined heat and power production (CHP) in the EU, Summary of statistics 1994-1998*. Statistical Office of the European Communities, 2001.
- Ezekiel, Ron and Wilson, Paul (2002), *GHG Emissions Trading Workshop – Negotiating an Emission Trade*,” presentation at conference sponsored by Climate Change Central, Calgary, Alberta, 21 February 2002.

- Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2001), *The German Emissions Trading Programme*, September 28, 2001.
- Haites, E. & Mullins, F. (2001), *Linking Domestic and Industry Greenhouse Gas Emissions Trading Systems*. Prepared for EPRI, IEA and IETA. October 2001. Available at [www.ieta.org](http://www.ieta.org)
- Harrison, D, Radov, DB.(2002), *Evaluation of Alternative Initial Allocation Mechanisms in a European Union Greenhouse Gas Emissions Allowance Trading Scheme*. Prepared for DG Environment, March 2002. Available at [www.europa.eu.int/comm/environment/climat/allocation.pdf](http://www.europa.eu.int/comm/environment/climat/allocation.pdf)
- Hasselknippe, H. & Høiby, G. (2001), *Meeting the Kyoto Protocol Commitments, Summary of domestic emissions trading schemes*. January 2001. Available at [www.nho.no](http://www.nho.no)
- IPCC (1996), *IPCC Guidelines for National Greenhouse Gas Inventories*. Intergovernmental Panel on Climate Change, 1996.
- Larsson, E. (2002), staff member of the Swedish District Association, Personal communication 2002.
- International Energy Agency (2001), *International Emission Trading – From Concept to Reality*. Paris 2001.
- OECD/IEA (2000), *Emission Baselines – Estimating the unknown*, Paris 2000.
- Pedersen, S.L. (2000), *The Danish CO<sub>2</sub> Emissions Trading System*, *RECIEL* 9(2000):3, 223-231. 2000. Available at [www.energistyrelsen.dk/uk/energy\\_reform/emissions\\_trading/index.htm](http://www.energistyrelsen.dk/uk/energy_reform/emissions_trading/index.htm)
- PointCarbon (2002). Article in Carbon Market Analyst Online, 7 March 2002. [www.pointcarbon.com/article\\_view.php?id=1719](http://www.pointcarbon.com/article_view.php?id=1719)
- PointCarbon (2002). Article in Carbon Market Analyst Online, 2 May 2002. [www.pointcarbon.com/article\\_view.php?id=1784](http://www.pointcarbon.com/article_view.php?id=1784)
- Protermo (1999), *Guidelines for Calculating Energy Generation in Combined Heat and Power Plants*, April 1999. Available from [www.energia.fi/sky/english/index.html](http://www.energia.fi/sky/english/index.html)
- Protermo (2000), *Manual for Calculating CHP Electricity and Heat*, January 2000. Available from [www.energia.fi/sky/english/index.html](http://www.energia.fi/sky/english/index.html)
- Rosenzweig, R., et al (2002), *The Emerging International Greenhouse Gas Market*, Pew Center on Global Climate Change, March 2002.
- Shiple, AM, et al.(2001), *Certification of CHP Systems: Establishing Emissions Standards*. ACEEE Report no IE014, September 2001. Available at [www.aceee.org/pubs/ie014full.pdf](http://www.aceee.org/pubs/ie014full.pdf) . Also reprinted as *Setting New Standards: The benefits for CHP*. Cogeneration and On-Site Power Production 3(2002):1, 51-58.
- Spurr, Mark (2001), *Role of District Heating & Cooling and Emissions Trading in Expanding Use of CHP*, presentation at the Second International CHP Symposium, May 2001.
- Swedish Ministry of Industry, Employment and Communications (2000), *Emissions Trading: A Way of Achieving the Climate Goals*, 2000.
- Topp, A. (2002), *KWK-Modernisierungsgesetz ante portas – Was ist zu tun*. Euroheat & Power 31(2002):3, 34-44.
- Tradeable Permits Working Group (2000), *Options Report: Using Tradeable Emissions Permits to Help Achieve Domestic Greenhouse Gas Objectives*, Ottawa, April 2000.
- UK, Department of the Environment, Transport and the Regions (2000), *The CHPQA Standard – Quality Assurance for Combined Heat and Power*, Issue 1, November 2000, Available at [www.chpqa.com](http://www.chpqa.com)

World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI) (2001), *The Greenhouse Gas Protocol: a corporate accounting and reporting standard*, Brussels, October 2001.

# Appendix 1: DHC/CHP Policy Paper

## District Heating and Cooling: Environmental Technology for the 21<sup>st</sup> Century

### Introduction

District heating and cooling (DHC) is an integrative technology that can make significant contributions to reducing emissions of carbon dioxide and air pollution and to increasing energy security. The IEA Committee on DHC and CHP<sup>1</sup> is concerned that DHC is being overlooked by decision-makers in the IEA, European Commission and national governments. There are myths and misconceptions about DHC based, in part, on poorly maintained systems in the Central and Eastern European (CEE) countries. These misconceptions cloud the real fact that, where based on waste heat utilisation these systems are more efficient than the direct use of natural gas, and provide many opportunities to increase use of renewable energy sources. This policy paper has been produced in order to help policy-makers better understand the benefits of DHC and the important role DHC can play in meeting Kyoto targets and other environmental and energy policy goals.

**DHC is a simple but powerful idea: connect many thermal energy users to environmentally optimum energy sources**

The fundamental idea of DHC is simple but powerful: connect multiple thermal energy users through a piping network to environmentally optimum energy sources, such as combined heat and power (CHP), industrial waste heat and renewable energy sources such as biomass, geothermal and natural sources of heating and cooling. The ability to assemble and connect thermal loads enables these environmentally optimum sources to be used in a cost-effective way.

Some countries, particularly in Scandinavia, show a significant penetration of district heating of over 50% of the heat market. However, district heating has only a small fraction of the total heat market of the European Union (EU). Therefore the potential is large and varies in each country depending on past national policies. DHC is no longer of importance only in northern latitude countries. Increasingly, in many parts of the world the DHC concept is being implemented for cooling, either through distribution of chilled water or by using the district heating network to deliver heat for heat-driven chillers. In the United States and in other countries where cooling is important, use of district cooling has grown significantly. There are a variety of technologies for using waste heat to provide economical district cooling.

### Myths and Misconceptions

#### *District heating is not competitive with distributed systems*

District heating systems are by their nature local solutions, and have limited ability to raise capital and to absorb early losses. National or regional gas and power networks, with much larger capital bases, can often forward-price or discount new gas or power developments and thus appear more competitive compared to district heating. There has been a tradition of national policies that also tend to favour large-scale energy supply alternatives, rather than local initiatives. However, when examined on a consistent basis of total long-term cost including environmental impacts, DHC is in many cases the most competitive alternative, and is essential for fully exploiting the potential for CHP. Building owners are receptive to a long-term energy supply system that is fuel flexible. This insulates them from the impact of market price shocks. Linking buildings together through DHC enables installation of CHP and other technologies that are technically and commercially proven, economically viable and environmentally attractive.

**Linking buildings with DHC opens up technology options**

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<sup>1</sup> Executive Committee of the International Energy Agency (IEA) Implementing Agreement on District Heating and Cooling including Integration with Combined Heat and Power.

**Fuel cell and coal plant CHP on the same DHC network**

District heating has a long history. As a technology concept it is a significant presence in many countries and is implemented in many different forms. As discussed below, district heating will increasingly move away from fossil fuels, toward recovery and use of waste from power plants, municipal waste and biomass. Network systems are required in order to maximise the environmental benefit of new power technologies such as fuel cells and high efficiency gas turbines as well as older technologies such as coal-fired power plants. The heat recovered through CHP or other energy sources can be converted to cooling, and worldwide implementation of district cooling is growing. In addition to integrating the best of new energy supply technologies, there has been and will continue to be progress in improving and reducing the cost of DHC pipe networks.

*District heating systems in Central and Eastern Europe are a sinkhole for investment*

**DHC networks in CEE create opportunities to increase CHP**

The poor performance of district heating systems in the CEE countries is due to the centralized imposition of a single design concept in a non-market economic system. The major technical innovation of pre-insulated pipes could not be used because it was Western technology that could not be imported. Significant efforts are now being made by many parties to bring the networks up to the required technical standard. The expansion of the gas system in some cases does not consider the full environmental advantage of using the premium fuel to first produce power, and then use the refurbished district heating network to supply buildings with the rejected waste heat. Policy-makers need to recognise these networks as a national environmental asset rather than as liabilities.

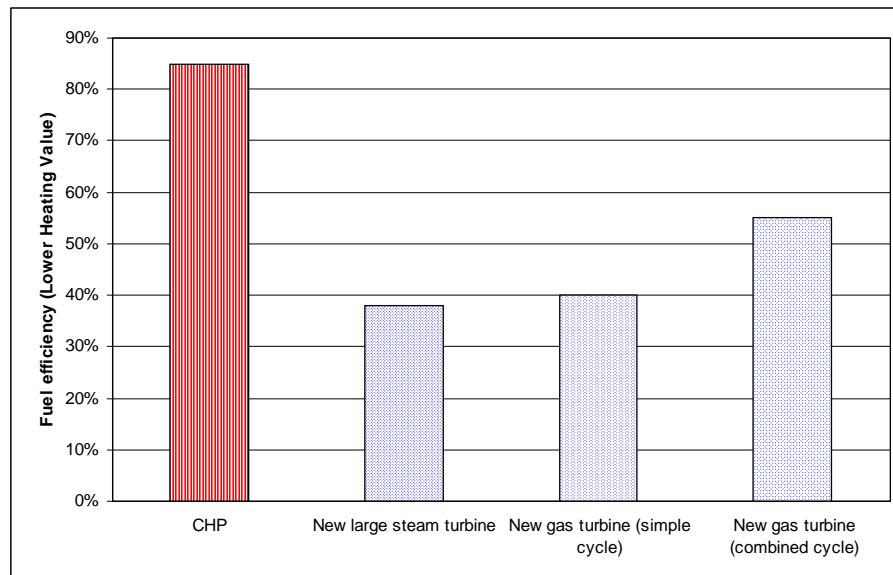
**Impact on Key Policy Issues**

Because DHC is an integrative and facilitative technology, it is relevant to many policy areas and should be considered in the preparation of national and supranational policies.

*CHP in the context of growing power demand*

**CHP enables growing power demands to be met efficiently**

Electrical demand continues to grow worldwide, with corresponding requirements for new power plants. Power plants generate large quantities of low-grade heat, which is wasted unless the plant is designed and operated as a CHP facility, as illustrated in the figure below.



DHC is important for implementing CHP because it expands the pool of potential users of recovered thermal energy beyond the industrial sector to include commercial, institutional and multi-unit residential buildings. The temperatures required by these users are relatively low, which allows CHP to operate at higher efficiencies compared to plants producing higher-temperature industrial process heat. In addition, as industry becomes more electrically intensive, large industrial heat sinks for low-grade energy are increasingly hard to find. Urban buildings, accessed through DHC, are a more stable long-term partner for CHP plants.

## *Carbon dioxide reduction*

**Avoided CO<sub>2</sub> from current DHC/CHP is about half of the total Kyoto goal**

Greenhouse gas abatement will be among the most important policy goals in the next century. DHC and CHP have already made enormous contributions to controlling GHG emissions, and have the potential for significant additional contributions to this important international goal.

Annually, about 11-12 ExaJoules (EJ) heat are generated and delivered to district heating systems in the world. The corresponding heat deliveries represent about 5 % of the total final energy demand in the industrial, residential, public, and commercial sectors. This fraction is lower in the OECD-countries (2 %) and higher in the non-OECD-countries (7 %).

Avoided carbon dioxide emissions from the use of district heating (DH)<sup>2</sup> and combined heat and power (CHP) is significant and is about half of the magnitude of carbon dioxide reduction presumed in the Kyoto protocol. Globally, DH and CHP (including industrial CHP) reduces existing carbon dioxide emissions from fuel combustion by 3-4%, corresponding to an annual reduction of 670-890 Mton compared to global emissions of 22700 Mton during 1998. The highest carbon dioxide reductions from DH/CHP occur in Russia (15%), in the former USSR outside Russia (8%) and in the EU (5%).

Carbon dioxide reductions from DH/CHP will decrease when the carbon dioxide emissions from alternative generation of electricity and heat are reduced. However, this is not a unique situation for DH/CHP; it will apply to all carbon-lean technologies, since the future competition will not come from carbon-rich technologies, but from other carbon-lean technologies.

For the future, DHC/CHP can make further reductions of global carbon dioxide emissions. This can be accomplished by:

- increasing the market penetration of DHC through new and expanding existing DHC systems;
- increasing the share of CHP in existing DHC generation, since only 48% is currently produced from CHP; and
- fuel substitution in existing DHC/CHP plants, since coal constitutes 38% of fuel supplied.

## *Biomass transition*

**DHC provides a flexible infrastructure for transition to renewable fuels**

In the longer term, policy papers indicate that biomass fuels will have to play the majority role in any renewable energy future.<sup>3,4</sup> There is little recognition that district heating systems are already supplying urban centres with heat from CHP plants fired with municipal wastes, wood waste and other biomass materials. These are in fact prototypes of the kind of plants that would convert future fuel crops into low-grade heat. However, the crucial importance of network solutions appears missing from almost all present analysis of new and renewable technology solutions.

## *Urban quality of life*

**Cities are where the energy problems are, and that is where DHC works best**

DHC is most effective in areas of high building density. The trend toward worldwide urbanisation offers a growing market, particularly in emerging economies and in the area of district cooling. Growing urbanisation presents significant energy and environmental challenges, and DHC can be an important part of a sustainable urban development policy. DHC network technology supports urban design that uses space well and can be served by energy efficient transit systems. DHC helps control urban air pollution, improving the quality of life and the vitality of city centers.

## *Energy market liberalisation*

**Energy market liberalisation both hurts and helps DHC/CHP**

The trend toward transnational and regional electric and gas networks both hurts and helps DHC and CHP. It is important to recognize that with energy market liberalisation the focus on short-run financial performance works against implementation of capital-intensive sustainable technologies

<sup>2</sup> In the analysis, only contributions from DH/CHP are considered. District Cooling (DC) is omitted from the analysis, due to a relatively low market penetration and lack of relevant statistical information.

<sup>3</sup> New and Renewable Energy: Prospects for the 21<sup>st</sup> Century DTI Consultative Paper.

<sup>4</sup> Energy for the Future: Renewable Sources of Energy. White paper for a Community Strategy and Action Plan COM(97) 599 26/11/97

such as DHC and CHP. On the other hand, the trend towards distributed power will increase the focus on small-scale DHC systems that will be as efficient as large-scale electric power plants.

The transnational power market is depressing the value of power, priced on short-run marginal costs, with older coal-fired condensing plants increasing market share – often at the expense of highly efficient CHP plants. Volatile and generally high gas prices have squeezed the “spark spread” for gas-fired CHP, making it difficult to implement new schemes and putting some existing schemes out of business.

Gas networks are both a competitor and an ally of DHC. National and international gas distributors have much more market power than district heating systems that are by their nature local and often municipal in structure. On the other hand, availability of a clean burning fuel enables small scale CHP and small block central networks to be competitive, creating new markets for gas, particularly in district cooling applications.

#### *Energy security*

**DHC and CHP provide many energy security benefits**

Energy security is an increasingly important national and supranational policy issue. DHC and CHP can play a key role in increasing energy security by:

- *Facilitating power generation in load centers.* By generating power close to the load, CHP avoids or reduces power transmission and distribution constraints.
- *Reducing cooling-related peak power demand.* Air conditioning is a big contributor to peak power demands. By supplying cooling through highly efficient electric chillers and non-electric, heat-driven chillers, district cooling reduces peak power demand.
- *Shifting demand to off-peak periods.* DHC can shift power loads to off-peak periods through thermal energy storage systems that store hot water, chilled water or ice at night for use during the day, or by shifting loads seasonally through aquifer or other long-term storage.
- *Increasing fuel flexibility.* DHC systems boost reliability and energy security by providing flexibility to use a variety of domestic resources, thereby reducing the impact of supply and price variations.

#### **Conclusions and Recommendations**

As policy initiatives, such as the European Union’s CHP Directive, the UK CHP initiative and the US CHP Challenge are developed, it is essential that these initiatives include strong and effective measures and that DHC be a key element in the solution. Although facilitation of CHP is currently the focus for these policy initiatives, the ability of DHC networks to use many heat sources including renewable energy is of great national and international value.

**Take steps now to internalise the benefits of DHC and CHP**

The environmental and energy security benefits of DHC and CHP are not currently priced in the marketplace. Unfettered market forces tend to result in solutions that may be shorter-term than is optimum for society and discriminate against capital-intensive technologies such as DHC. It is essential that steps be taken now to internalise the environmental and energy security benefits of DHC and CHP.

When a carbon dioxide emissions trading scheme is fully operational this will be an important step toward internalisation of environmental externalities. However, such a system will not be fully functioning until 2008 or later, and without action to address barriers the development of DHC and CHP potential will be seriously hampered. In addition, carbon dioxide emissions trading will not address the other environmental benefits of CHP resulting from reductions in emissions of air pollution, nor will it provide recognition of the energy security benefits.

An appropriate and feasible place to begin to address internalisation of CHP and DHC benefits is in tariffs and procedures governing interaction of CHP facilities with the power and gas grids and in energy and emissions taxation. There are a number of areas related to interaction of CHP facilities with the power grid where treatment of CHP facilities can be improved to at the very least provide a level playing field, and in some areas provide an appropriate means of recognizing the environmental and energy security benefits of DHC/CHP. Many of these issues will disappear when the transition to a fully functioning liberalised market is completed. However, until that transition is successful, a number of issues remain problematic in many markets, including:

**Ease barriers to connection of CHP to power and gas grids**

- Guarantee of access to transmission and distribution systems;
- Technical standards for interconnection of CHP facilities to the grid;

- Bearing of costs relating to grid connection and grid reinforcement;
- Tariffs for sale of surplus power to the grid;
- Tariffs for use of grid to transport power to buyers; and
- Tariffs for purchase of back-up and top-up power.

Policies should be implemented so that CHP facilities have access, under transparent and non-discriminatory terms, to the grid.

- A model interconnection standard would be a useful step. Technical standards and approval processes for interconnection should not be the burden they often are today.
- Limits should be established for grid connection cost per MegaWatt such that costs above this threshold are borne by the grid rather than the individual CHP facility. This would provide some recognition of the grid benefits of smaller CHP plants that supply power to the grid and/or reduce grid power demand but for whom the fixed costs of interconnection are a significant burden. A simple mechanism such as this is preferable to a complex, case-specific analysis of grid constraints.
- The EU should monitor and report on progress toward fair and non-discriminatory interconnection guidelines on a country by country basis, and highlight findings regarding anti-competitive practices that restrict the implementation of CHP.

**Ensure that taxes do not penalise environmentally beneficial technologies**

Energy and emissions taxes should not penalise environmentally beneficial technologies. Heat from CHP plants should not be taxed at the same level as heat produced in heat-only boilers.

**Set CHP implementation targets**

An important policy framework is establishment of implementation targets and use of flexible mechanisms for achieving those targets. The Tradeable Green Certificate (TGC) developed for renewable generation is a concept that can and should be applied to CHP. EU and national targets for CHP implementation should be established, with fulfilment directly or through TGCs.

Emissions trading could facilitate significant additional GHG reductions through DHC and CHP, but GHG trading programs must be designed properly to address issues relating to sectors coverage, allocation and entity boundaries.

**Emissions trading can facilitate large additional GHG reductions from DHC/CHP**

It is important that equivalently stringent GHG emission constraints be placed on building heating systems through other policies and measures. Alternatively, cap-and-trade emissions trading programs should credit a DHC system for its impact on total emissions in the allocation of allowances or in the determination of the quantity of allowances required to be surrendered by a DHC system.

The most appropriate GHG emission allowance allocation system would be based on emissions per unit of product output. Allowance allocation should recognise the total GHG reduction benefits of DHC and CHP. For example, a CHP project should receive allocations from both the power sector allocation and the heat sector allocation, and a DHC system should get credit for offset building boiler emissions. Allowance allocations should recognize the total emission reduction benefits of CHP even if the legal entity implementing CHP is separate from the entities purchasing the CHP power and heat output. The allocation for CHP power output should reflect the marginal capacity of the grid during the time period in which the facility operates.

Project-based trading mechanisms provide an opportunity to credit the total emissions benefits of a DHC/CHP project, but it is important that such programs credit the avoided power production emissions based on marginal grid capacity on the power side and the avoided heat production emissions even if it is in the buildings sector.

**The IEA DHC/CHP Executive Committee would welcome the opportunity to provide further information to IEA policy studies, the EC, national governments and others that are responsible for reducing greenhouse gas emissions, cutting air pollution and increasing energy security.**

[www.iea-dhc.org](http://www.iea-dhc.org)

This policy paper was approved by the International Energy Agency Executive Committee for the Implementing Agreement on District Heating and Cooling including the Integration of CHP at its 38<sup>th</sup> meeting in Copenhagen on 16 May 2002.



## Appendix 2: Policy Presentation

### **District Heating and Cooling: Environmental Technology for the 21<sup>st</sup> Century**

**International Energy Agency  
Implementing Agreement on  
District Heating and Cooling including  
integration with Combined Heat and Power  
(IEA DHC/CHP)**

Picture 1

### **Agenda**

- Fundamentals
- Myths
- Benefits of DHC
- Carbon emissions comparison
- Emissions trading program design
- Recommendations

Picture 2

### **Fundamentals**

- DHC concept is simple but powerful: connect many thermal energy users to environmentally preferable energy sources:
  - Combined heat and power (CHP)
  - Industrial waste heat
  - Renewable energy sources such as biomass, geothermal and natural sources of heating and cooling
- DHC's ability to integrate thermal loads enables these preferable sources to be used cost-effectively

Picture 3

## Myths

- **Myth:** District heating is not competitive with distributed systems
- **Reality:**
  - District heating in many cases has the lowest long-term costs, particularly if environmental benefits are internalized
  - Long-term perspective is needed because of DHC capital intensiveness, particularly in early stages
  - Need to counter past policies favoring large-scale infrastructure (power and gas networks) over local systems

Picture 4

## Myths

- **Myth:** District heating systems are yesterday's technology
- **Reality:**
  - DHC, including heating and cooling, continues to grow
  - DHC technology continues to progress
  - DHC is key to expanding use of CHP and renewable energy
  - DHC is highly relevant because of its environmental and energy security benefits

Picture 5

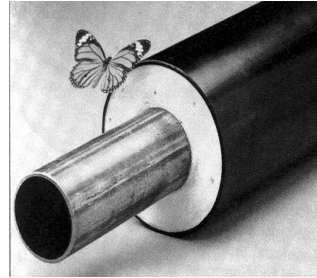
## Myths

- **Myth:** District heating systems in Central and Eastern Europe are a sinkhole for investment
- **Reality:**
  - Poor performance due to centralised imposition of rigid design concept in non-market economic system
  - Significant upgrades are occurring
  - These systems represent important CHP and renewable energy opportunities

Picture 6

## District Heating and Cooling Today

- DHC and CHP reduces current CO2 emissions by 670-890 million metric tons
- Equal to 3-4% of total global emissions
- Equal to about half the Kyoto goal



Picture 7

## DHC Can Further Reduce GHG

- Existing DHC used as thermal sink for CHP (48% of current district heat comes from CHP)
- New DHC and expansion of existing systems, integrating loads to distribute energy from:
  - CHP
  - Industrial waste heat
  - Biomass
  - Natural sources of thermal energy
- Fuel substitution opportunities; DHC is flexible infrastructure for transition to renewables

Picture 8

## DHC Increases Energy Security

- Increases supply diversity and use of local energy sources
- Reduces demand on power grid
  - Delivers cooling energy through district cooling rather than power grid
  - Shifts demand to off-peak periods with thermal storage
- Strengthens power grid reliability
  - Generates power at load centers through CHP

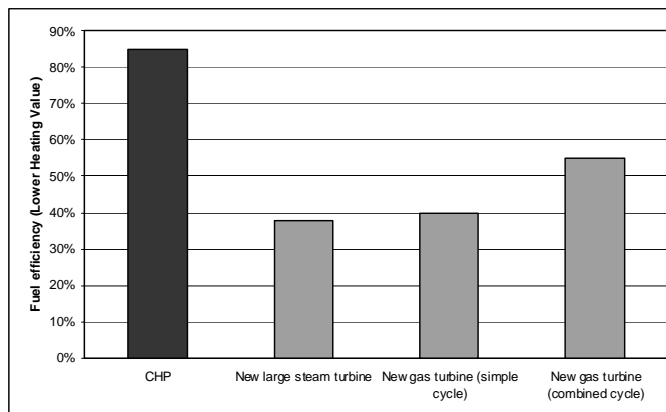
Picture 9

## Market Liberalisation Hurts

- Transnational power market is depressing the value of power, priced on short-run marginal costs
- High gas prices squeeze the spark spread
- Volatile gas prices introduce uncertainty
- In Europe, cheap/old/dirty condensing plants push out CHP
- No corresponding market for environmental externalities
- Emissions trading can provide a solution if properly implemented

Picture 10

## CHP is highly efficient



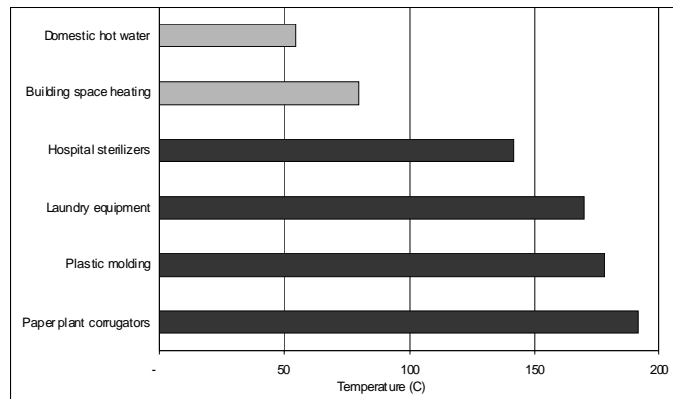
Picture 11

## DHC is an important CHP opportunity

- Low-temperature thermal sink
  - Efficient CHP
  - Higher power output
- Low-carbon options for building heating
- Combine heating and cooling to provide high load factor for CHP
- Flexibility for transition to biomass

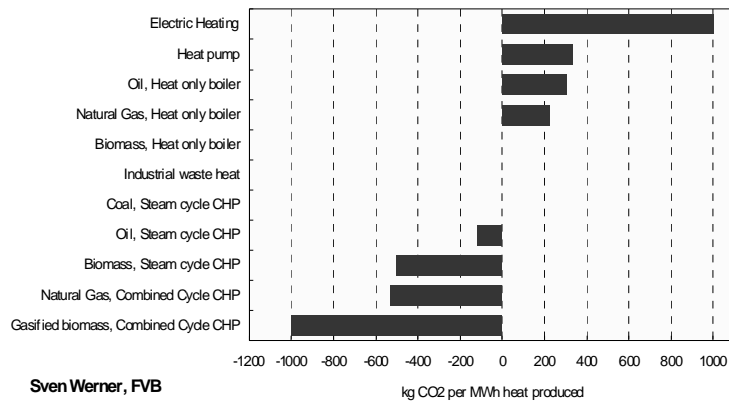
Picture 12

## DHC accesses low-temperature heat sinks



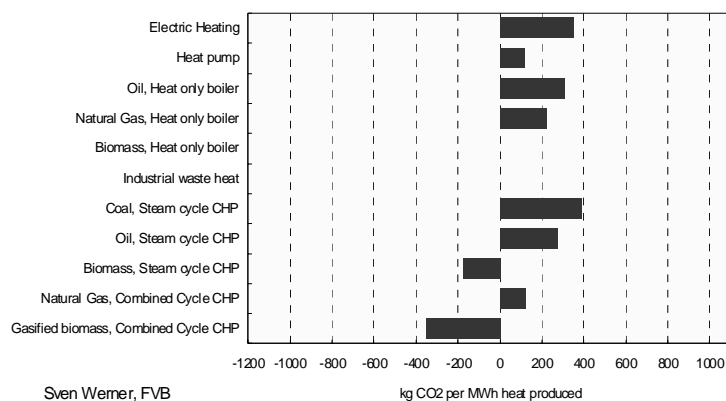
Picture 13

## CO<sub>2</sub> Emissions From Heating Options with Current Marginal Power



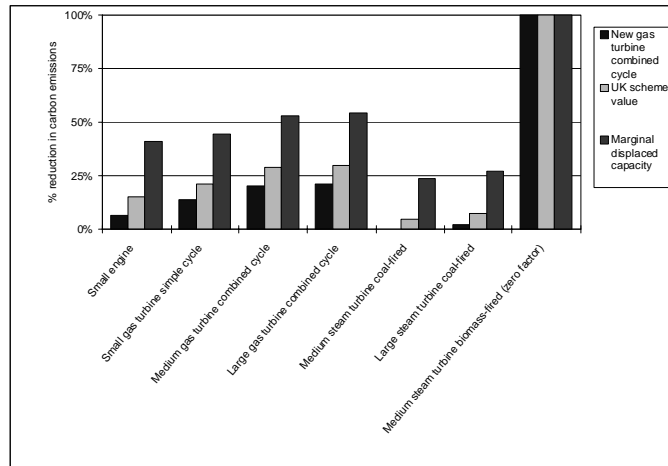
Picture 14

## CO<sub>2</sub> Emissions From Heating Options with Future Marginal Power



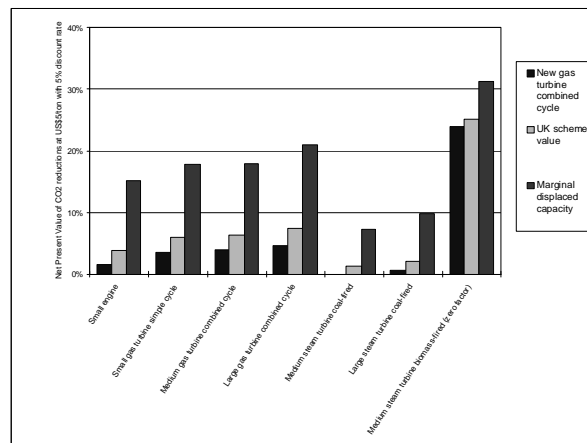
Picture 15

## Net CO<sub>2</sub> Reduction with CHP Options



Picture 16

## NPV of CO<sub>2</sub> Reductions as % of CHP Capital Cost at US\$15/metric ton



Picture 17

## Emissions Trading Program Design

- Cap-and-trade vs. project mechanisms
- Allowance allocation
  - Grandfathering
  - Benchmarking
  - Auction
- Boundary issues
  - Power sector
  - Heat sector
  - Buildings sector
  - Third party developers

Picture 18

## Trading Program Recommendations

- Trading schemes should recognize total emissions impact of DHC and CHP:
  - CHP plant
  - Eliminated heat-only boiler emissions, including in building sector
  - Eliminated grid emissions from power sales to grid or reduced purchases from grid
- Value for offset grid emissions should reflect marginal grid capacity

Picture 19

## Recommendations

- Take steps now to internalise environmental and energy security benefits of DHC and CHP
  - Mitigate negative impacts of liberalisation
  - Internalise GHG benefits in advance of fully functioning GHG emission trading
  - Internalise air pollution and energy security benefits

Picture 20

## Recommendations

- Address grid access
  - Model interconnection standard
  - Establish limit on grid connection costs
  - EU should monitor Member State progress
- Address tax issues
  - Tax on heat from CHP should reflect environment benefit

Picture 21

Thank you for your attention!

## Questions?

Contact information:

IEA Implementing Agreement on DHC/CHP

Phone +31-46-420-2332

Fax +31-46-452-8260

E-mail [M.Wobben@novem.nl](mailto:M.Wobben@novem.nl)

Web home page [www.iea-dhc.org](http://www.iea-dhc.org)

Picture 22



# Appendix 3: Globally avoided carbon dioxide emissions during 1998 as a benefit from the current use of DH/CHP

Presented at the Euroheat & Power annual conference POWER TO THE HEAT, Brussels, March 5, 2002.

## Summary

Globally, District Heating (DH) and Combined Heat and Power (CHP) including industrial CHP reduces the existing carbon dioxide emissions from fuel combustion by 3-4%, corresponding to an annual reduction of 670-890 Mton compared to the global emission of 22700 Mton during 1998.

The lower estimate is based on the original IEA Energy Balances for 1998. The higher estimate considers a compensation for the lack of adequate statistical information in the IEA Energy Balances about CHP plants in China and heat generation from industrial CHP in the EU and USA. The highest carbon dioxide reductions from DH/CHP occur in Russia (15%), in the former USSR outside Russia (8%) and in the EU (5%).

Since DH/CHP has a low market penetration in the world today, DH/CHP is still a secret to many policy and decision-makers.

Globally avoided carbon dioxide emission from DH/CHP can be increased by

- increasing the market penetration of central heat generation by introducing new and expanding existing district heating systems.
- increasing the heat utilisation in existing CHP plants by expanding the local heat sales.
- increasing the share of CHP in existing central heat generation, since only 48% is generated in existing CHP plants. The possibility is higher in non-OECD countries, since the share of CHP is 75 % in OECD countries.
- fuel substitution in existing DH/CHP plants, since coal constitutes 38% of fuel supplied.

Globally avoided carbon dioxide emission from DH/CHP will decrease when the carbon dioxide emissions from alternative generation of electricity and heat will be reduced. However, this is not a unique situation for DH/CHP; it will apply to all carbon lean technologies, since the future competition will not come from carbon rich technologies, but from other carbon lean technologies.

## Introduction

This paper considers the recognition of the current amounts of avoided emissions from existing District Heating Systems (DH) and Combined Heat and Power (CHP) plants in the world.

Avoided emissions are defined as the difference between the replaced emissions from alternative electricity and heat generation and the current emissions from DH/CHP plants. This difference occurs since DH gives the possibility to distribute heat derived from industrial processes, refuse incineration, geothermal sources, and CHP plants. Dual (or triple) use of energy supplied reduce the demand of fossil fuels in the DH systems. DH can be seen as a second hand business within the energy sector. CHP generation has also a higher conversion efficiency than separate generation of heat and thermal power. DH/CHP also gives the possibility of a central fuel substitution from fossil fuels to non-fossil fuels, as biomass fuels. All these possibilities make DH/CHP a carbon lean technology.

The purpose of this paper is mainly educational and aims at the identification of carbon dioxide mitigation methods already in use. The logical conclusion from this paper should be: If mitigation methods are already operating today, they can be repeated and expanded for further reductions of carbon dioxide emissions tomorrow.

In the analysis, only contributions from DH/CHP are considered. District Cooling (DC) is omitted from the analysis, due to a low market penetration and lack of relevant statistical information.

The main information sources for the analysis are the 2001 editions of the Energy Balances for OECD and non-OECD countries published by International Energy Agency (IEA) in Paris. They contain the appropriate information, which the corresponding editions of Energy Statistics do not. Calorific values for fuels used together with electricity and heat generated must be available for CHP and DH plants on each national level. The magnitudes of the information gathered have also been checked against various other information sources listed in the concluding literature list.

The analysis is performed by presenting:

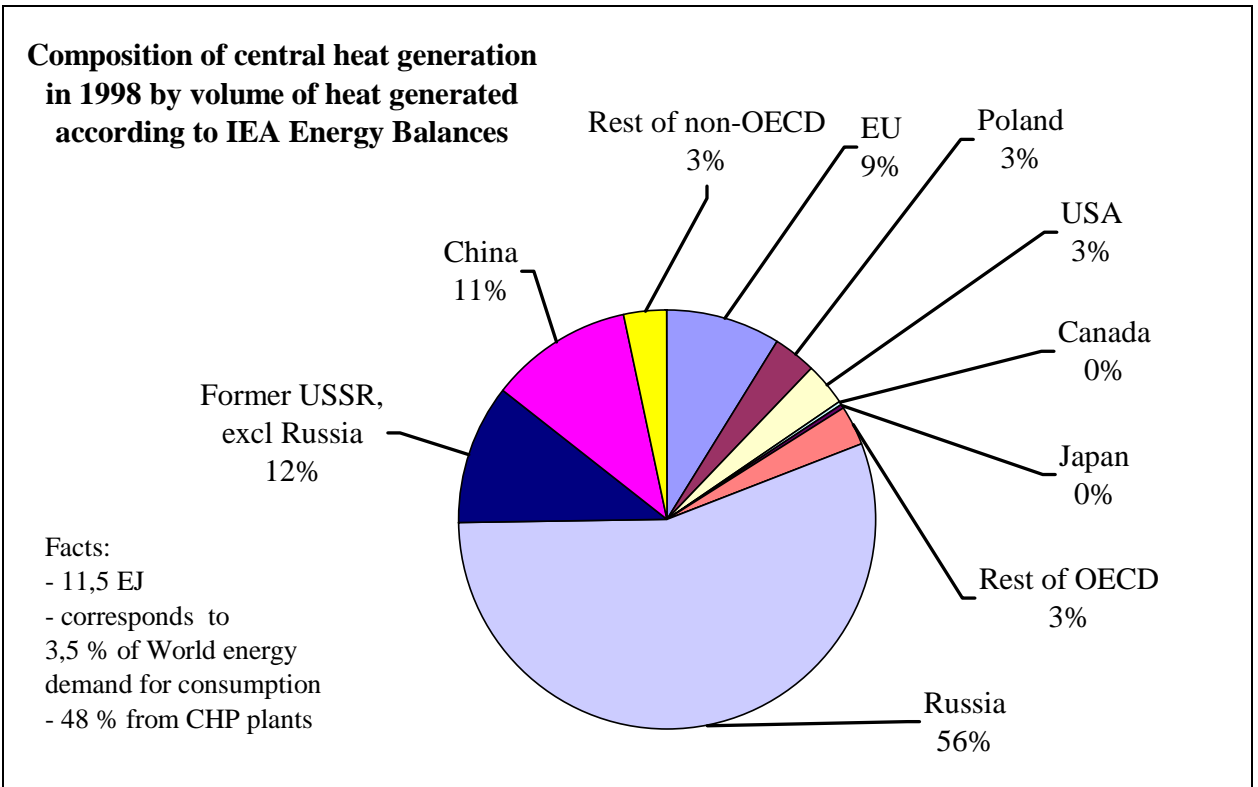
- Global heat demands connected to central heat generation
- Market penetration of central heat generation
- The energy supply compositions for DH/CHP and all electricity generation
- The conversion efficiencies for DH/CHP and all electricity generation
- The identification of statistical deficiencies
- Estimation of avoided emissions of carbon dioxide

### Global heat demands connected to central heat generation

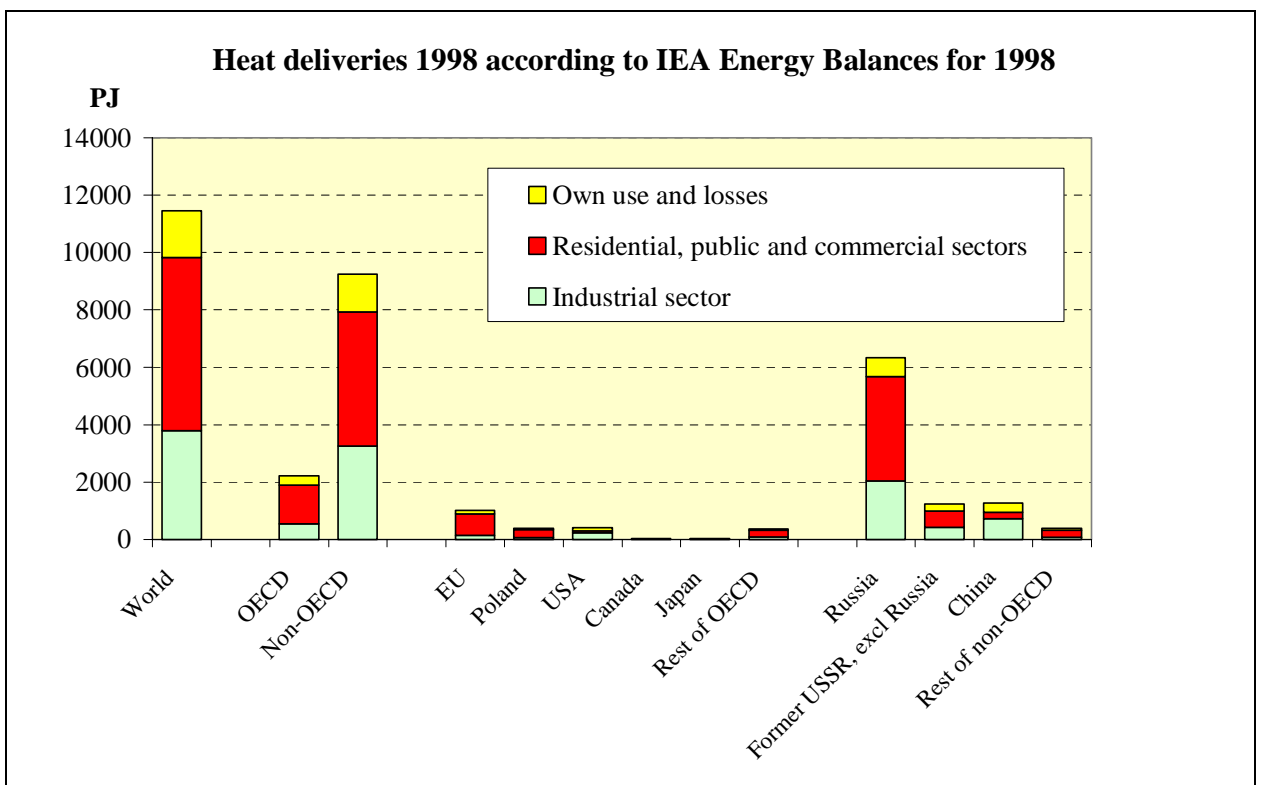
The total amount of the global central heat generation was 11500 PJ in 1998 and its geographical distribution is presented in **Figure 11**. This volume corresponds to 3,5 % of the world energy demand for consumption. China and the former USSR have almost 80% of all central heat generation in the world. Russia alone has 56 %, since DH/CHP was promoted in the planned economy in the former USSR. The OECD countries have only 18 % of the total volume of central heat generation.

The final energy demand for central heat generation was divided between industrial sector demand (39 %) and heating demands in the residential, public, and commercial sectors (61 %). Most of the industrial demands occur in non-OECD countries, according to **Figure 12**.

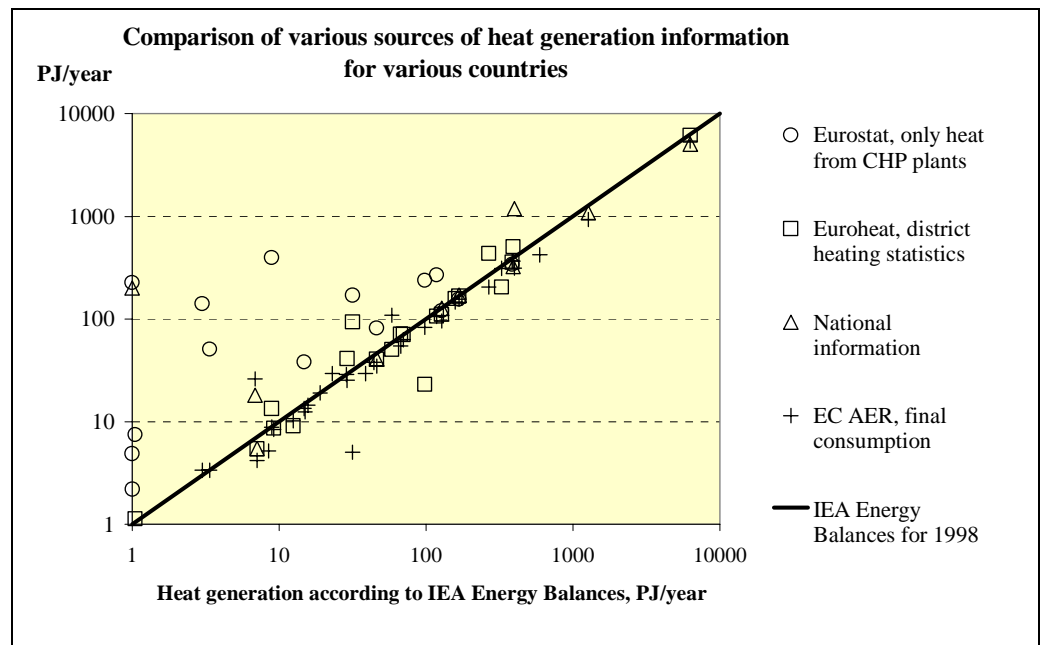
Globally, the share of CHP in central heat generation is only 48%. In many countries this share amounts to 60-90%. The averages for OECD countries and in the EU are 75 % and 81 %, respectively. Hence, more heat from CHP plants can be absorbed in heat systems supplied from central heat generation in non-OECD countries.



*Figure 11. Composition of global central heat generation with respect to geographical distribution..*



*Figure 12, Composition of global heat demands with respect to use and geographical distribution.*



**Figure 13.** Comparison between heat generation information in the IEA Energy Balances and other sources for heat generation and heat demand information. Each dot represents one country and one source of information. National information comes from national sources cited in the literature list.

The magnitudes of the information gathered have been checked against various other information sources listed in the concluding literature list. This comparison is presented in **Figure 13**.

It is obvious from **Figure 13** that the amounts of heat generated in CHP plants in the EU countries reported by Eurostat 2001 are considerable higher than the corresponding total heat generation information in the IEA Energy Balances. Other sources of information (Euroheat & Power 2001 and EC Annual Energy Review 2000) show a higher degree of conformity. It appears that electricity generated is included and heat generated is excluded for industrial CHP plants in the EU in the IEA Energy Balances.

The conclusion is that the heat generation volumes in the IEA Energy Balances corresponds quite well with other sources of information. However, for some countries, heat generation from industrial CHP plants is missing.

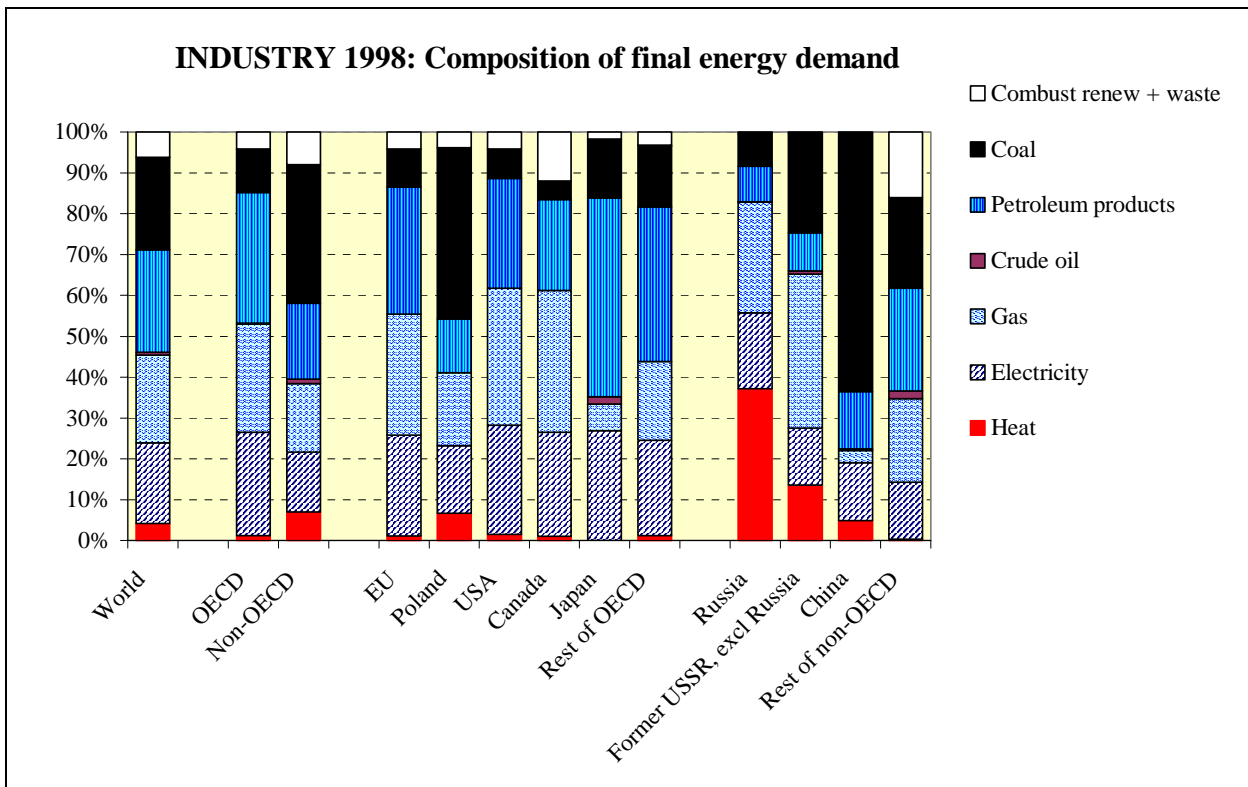
### Market penetration of central heat generation

The market penetration of central heat generation in final energy demand is presented for the industrial sector in **Figure 14**, while the residential, public and commercial sectors are presented in **Figure 15**.

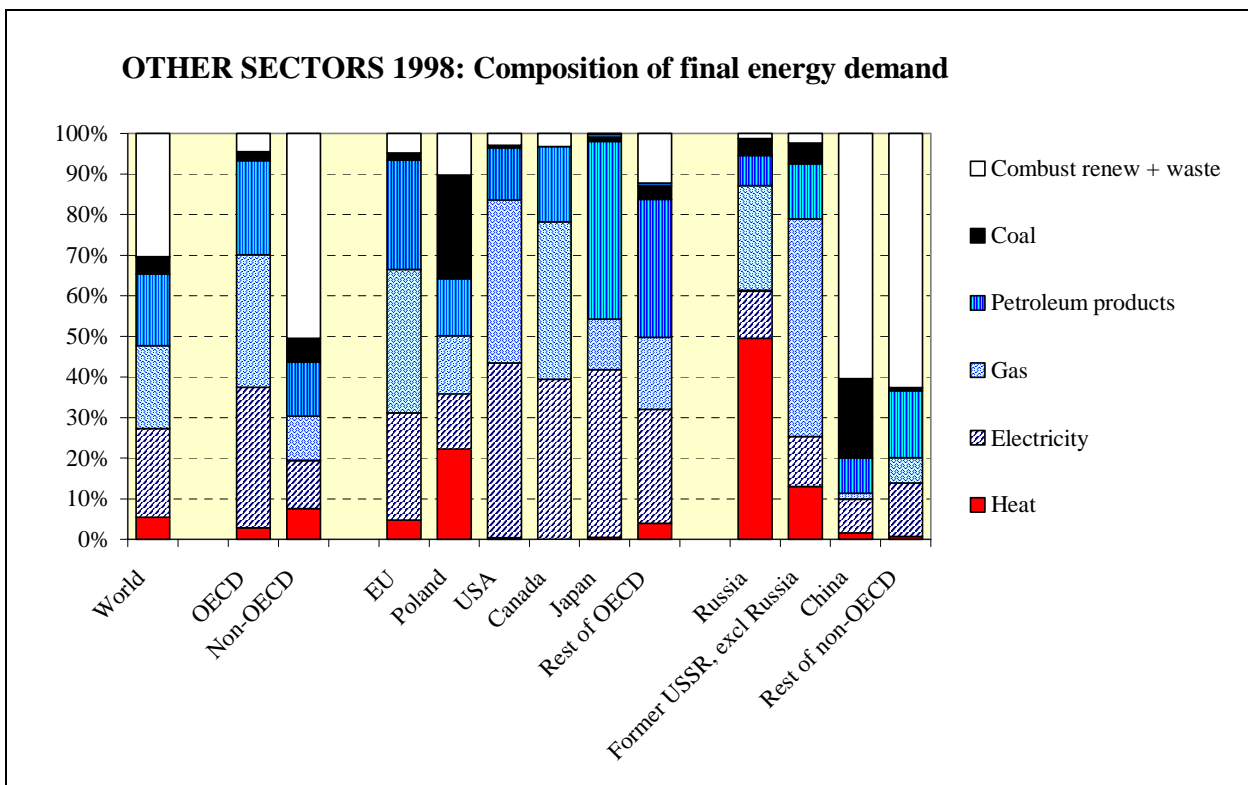
For the industrial sector, the energy demand is dominated by industrial processes. Central heat generation mainly appears in the former USSR, China and Eastern Europe. However, in OECD countries, industrial CHP plants belong to the industrial sector in the energy statistics and not to the energy transformation sector.

For the residential, public and commercial sectors, the energy demand in cold countries is dominated by the heat demand for heating buildings. Also for these sectors, the market penetration for central heat generation is high in the former USSR, China and Eastern Europe. Some market penetration also occurs in the EU. However, this market penetration is irregular within the EU. High market shares occur in Finland, Sweden, and Denmark according to **Figure 16**. Lower market shares appear in Germany, Austria and the Netherlands. The other 9 EU countries have almost no central heat generation. But since Germany has a large population, it has the largest district heating market with 386 PJ/year. In size, it is followed by Sweden (167 PJ), Denmark (128 PJ), and Finland (118 PJ).

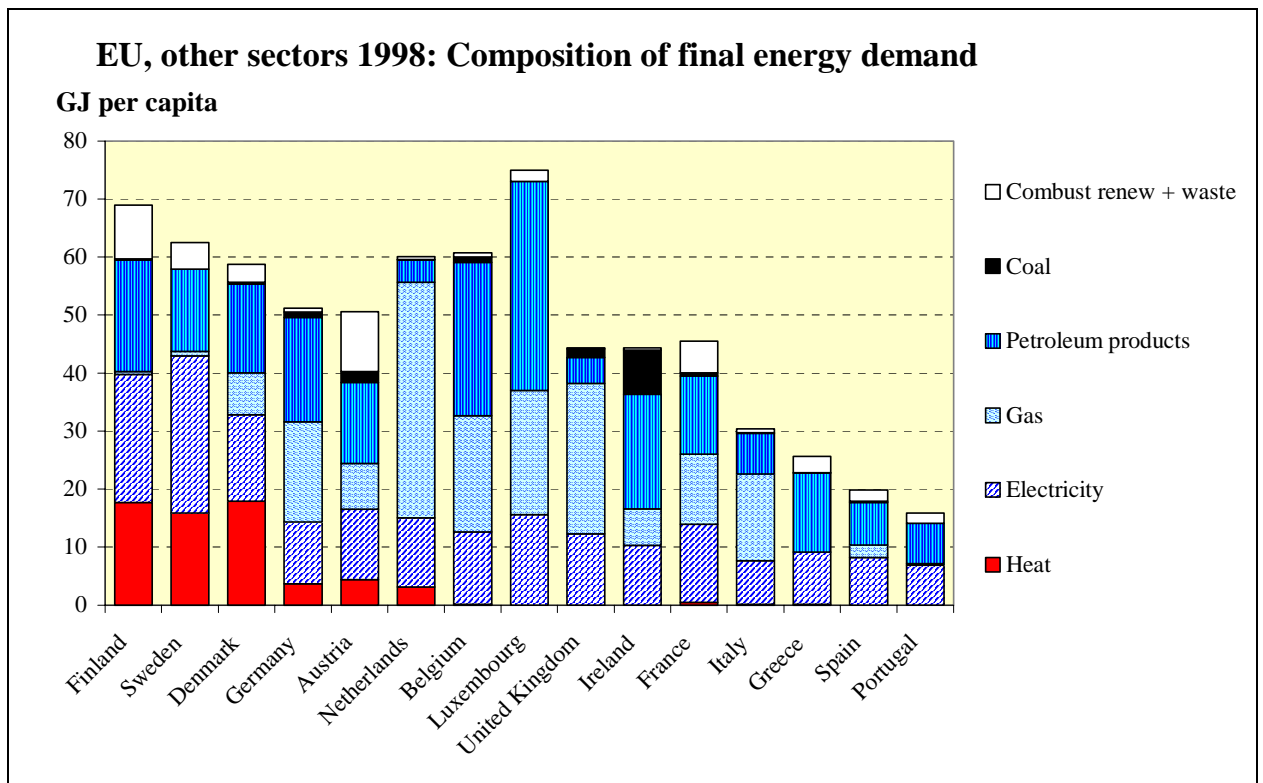
The conclusion is that the market penetration of central heat generation is low in the world. Only 4,2 % of industrial energy demands and 5,5 % of residential, public and commercial energy demands are globally met by central heat generation.



**Figure 14.** The current composition of the final energy demand for the industrial sector for various parts of the world.



**Figure 15.** The current composition of the final energy demand for the residential, public, and commercial sectors for various parts of the world.



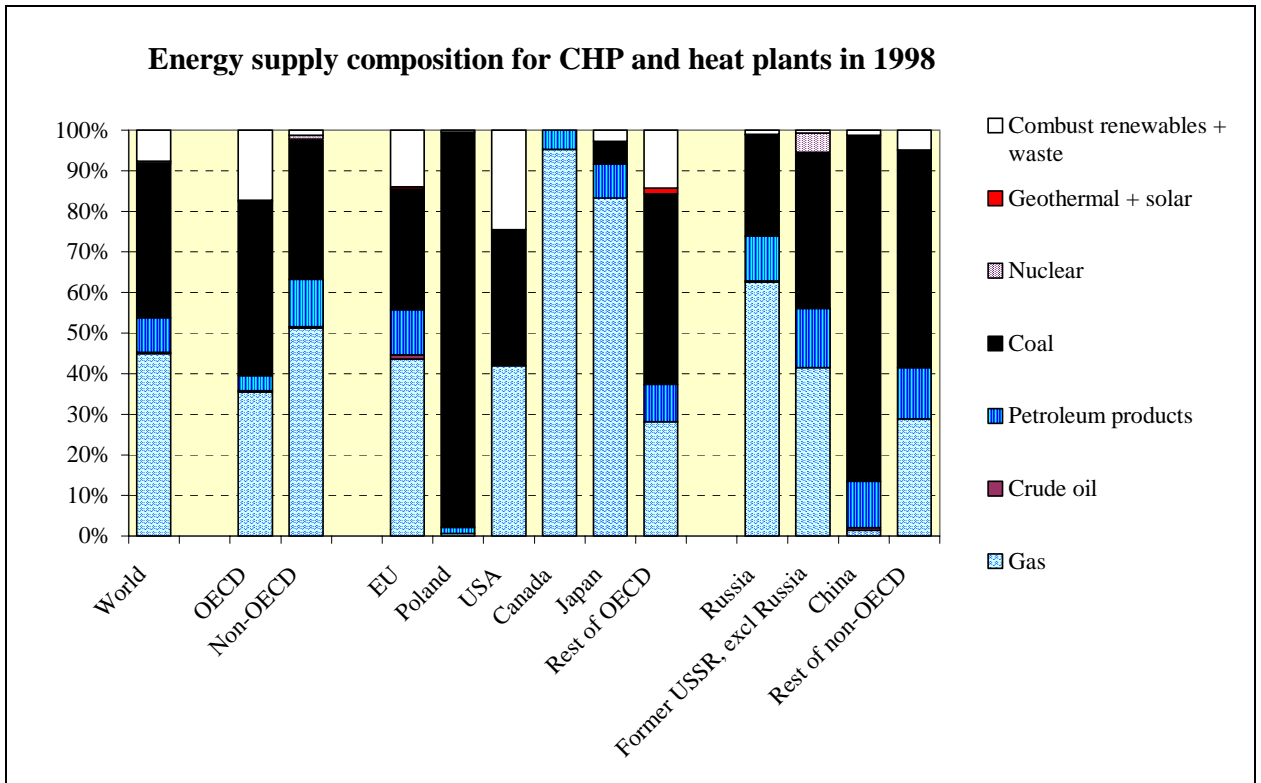
*Figure 16. The current composition of the final energy demand for the residential, public, and commercial sectors for the countries in the EU. In order to reflect various heat demands, the countries are presented from Northeast to Southwest.*

### Energy supply composition

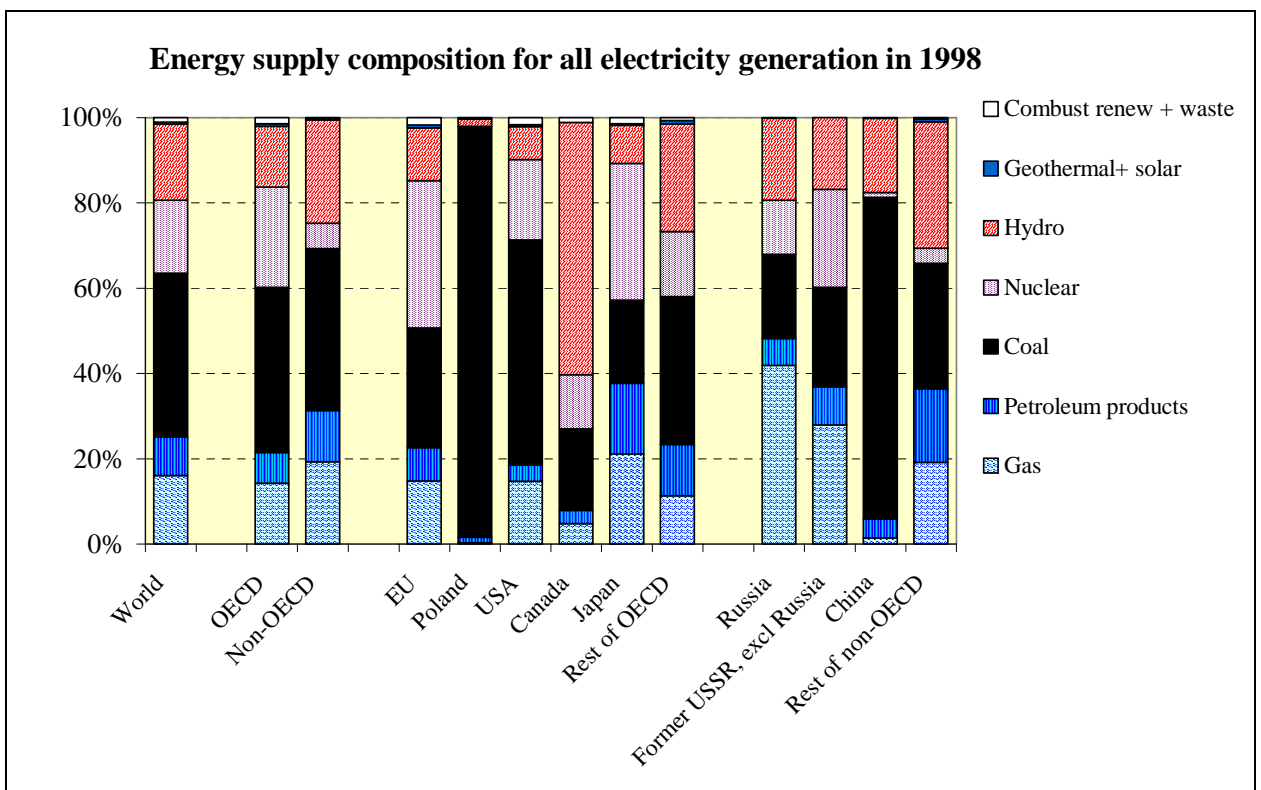
The energy supply composition for DH/CHP plants and all electricity generation are presented in **Figure 17** and **Figure 18**, respectively. DH/CHP plants use more natural gas and combustion renewables than conventional thermal power generation do. Hence, the fraction of coal in CHP plants are lower (38 %) than for conventional thermal power (67 %). Examples of countries that have high fractions of coal in the energy supply for both DH/CHP plants and conventional thermal power generation are Poland and China.

The average carbon dioxide emission for energy supplied is 66 g CO<sub>2</sub> per MJ for DH/CHP plants. The corresponding value for conventional thermal power generation is 83 g/MJ.

The conclusion is that existing DH/CHP plants are more carbon lean in the energy supply than conventional thermal power generation.



*Figure 17. The current energy supply composition for DH/CHP plants (with respect to calorific values of fuels used) for various parts of the world.*



*Figure 18. The current energy supply composition for all electricity generation (with respect to volumes of electricity generated) for various parts of the world.*

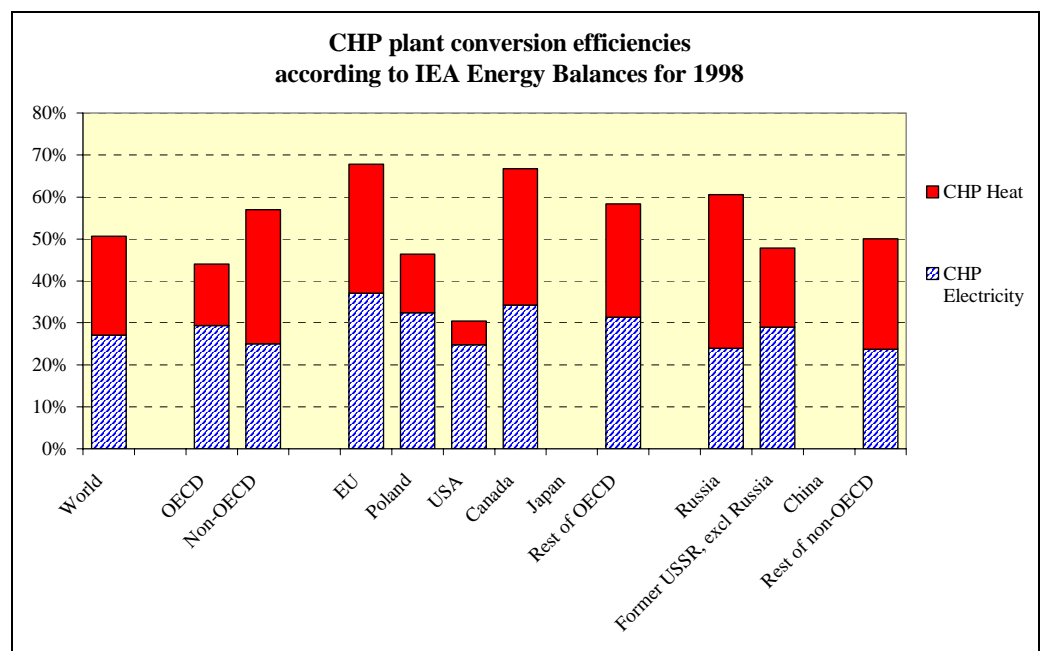
## Conversion efficiencies

The conversion efficiencies for CHP plants divided into the electricity and heat parts are presented in **Figure 19**. The global average is only 51 %. This implies that many CHP plants are also generating electricity in condensing mode without heat recovery. The highest conversion efficiencies are found in the EU (68 %) and Canada (67 %). Without operation in condensing mode, total conversion efficiencies of 85-90% are possible for CHP plants.

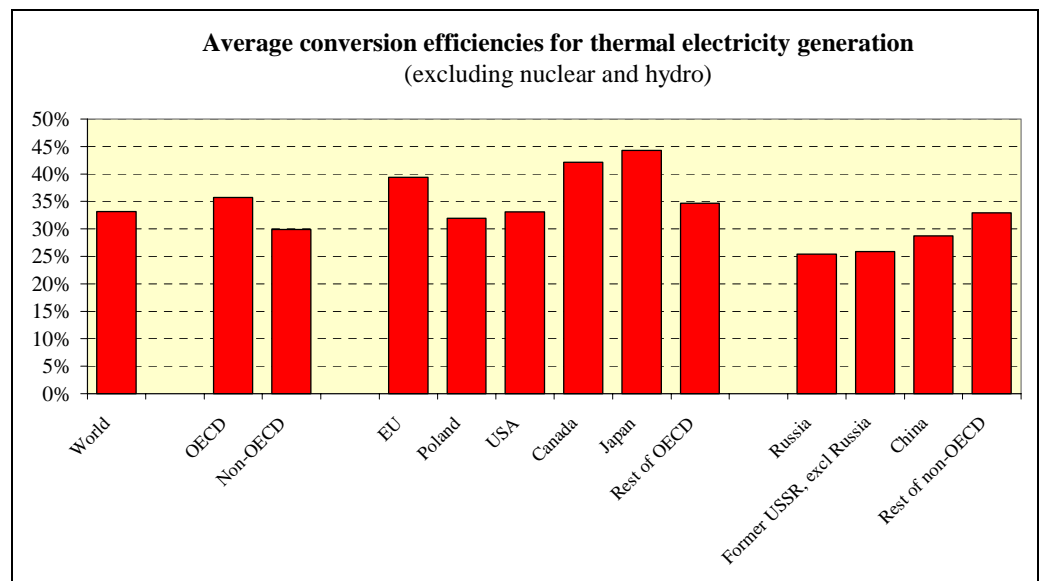
It appears that the heat generated in the US CHP plants is underestimated, since the overall conversion efficiency is only 30 %. Since all thermal power plants are considered as CHP plants in Poland, the total conversion efficiency is also low. No information are available about CHP plants in China and Japan.

For conventional thermal generation, the conversion efficiencies are really low. The global average is only 33%. The highest conversion efficiencies occur in Japan, Canada, and in the EU.

The conclusions are that alternative generation of electricity is associated with a low conversion efficiency and many CHP plants can probable deliver more heat since they also generate electricity in condensing mode.



**Figure 19.** Current average conversion efficiencies for CHP plants.



**Figure 20.** Current average conversion efficiencies for conventional thermal power generation.



## Identification of statistical deficiencies

The quality of international energy balances published by IEA has improved considerably during the recent years with respect to heat and CHP generation. However, due to different national statistical gathering routines, some deficiencies have been identified in the IEA Energy Balances. As a summary, the following statistical deficiencies relevant to this analysis are:

- EU: Heat generated in industrial CHP plants is not included. This is evident from a comparison with the heat amounts from CHP published in Eurostat 2001 and enclosed in the correlation analysis in **Figure 13**. It appears that fuels allocated for electricity are included in the CHP statistics, while fuels allocated for heat generation are included in the industrial heat demands. For UK, both heat generation from CHP and heat plants are missing. National information from UK reveals considerable amounts, National statistics 2000.
- Poland: All thermal power plants are considered to be CHP plants.
- USA: Low heat output from CHP plants. It appears that only fuel consumption and electricity generation are reported for many CHP plants.
- Canada: Information about heat plants are not available.
- Japan: No CHP statistics are available, only heat plants are reported.
- Russia: Almost all thermal power plants are considered as CHP plants.
- China: No CHP statistics are available, only heat plants are reported.

It appears that the most suitable statistical routines for gathering information about DH/CHP are found in the former USSR and Eastern Europe. In the former planned economy, the CHP plants were often built and operated separately from industrial enterprises and district heating systems. Hence, the routines for gathering statistical information seems still follow this traditional organisation. In the EU and USA, industrial CHP plants are integrated within the industrial enterprises. These countries have then no tradition of gathering CHP heat generation information from the industrial sector.

## Avoided emissions of carbon dioxide

Avoided emissions are defined as the difference between the replaced emissions from alternative electricity and heat generation and the current emissions from DH/CHP plants.

The estimations of avoided emissions are based on the following calculation procedure:

- The current emissions from DH/CHP plants: Total calorific values for fuels used have been multiplied with following emission factors: Coal – 92 g/MJ, oil products – 75 g/MJ, and gas - 56 g/MJ. No carbon dioxide emission is allocated from other energy supplied.
- Fuels avoided for electricity generation: Assumed conversion efficiency of 33 %, according to the average in **Figure 20**. Replaced fuel has been assumed to be coal, according to an analysis performed in Werner 2001. The calculation presumes central alternative electricity generation, since distribution losses are not deducted.
- Fuels avoided for heat generation: Assumed conversion efficiency of 80 % and average emission factor for country or region, dependent on fuels locally used. Average emission factor was 70 g/MJ. Highest factor for China (87 g/MJ) and lowest for Canada and Russia (65 g/MJ). The calculation presumes local alternative heat generation, since distribution losses are deducted from the central heat generation in DH/CHP plants.

The first set of estimations of avoided emission using the original IEA Energy Balances is presented for various regions and countries in **Table 1**. In total, 667 Mton of carbon dioxide emissions are avoided due to the existing use of DH/CHP. This corresponds to a reduction of 2,8 % of the global emissions from fuel combustion.

A second set of estimations is presented in **Table 2**. In this set, corrections have been made for inadequate information about the EU, USA and China in the IEA Energy Balances. The corrections made were:

- EU: Information about CHP plants (fuels used and heat generated) from Eurostat 2001 are used instead of information from IEA Energy Balances. By this change, also industrial CHP plants will be included in the analysis.
- USA: A total conversion efficiency of 60 % is assumed. No change in fuel supplied occurs since only the total conversion efficiency has been changed.

- China: A national power-to-heat-ratio of 0,3 is assumed in relation to total heat generated, giving 9,1 Mtoe (106 TWh) of electricity generated in CHP plants. The fuel supplied have been increased proportionally.

In total, 892 Mton of carbon dioxide emissions are avoided due to the existing use of DH/CHP according to this second set of estimations. This corresponds to a reduction of 3,8 % of the global emissions from fuel combustion.

***Table 1.** Calculation of avoided carbon dioxide emission due to DH/CHP plants according to the original IEA Energy Balances for 1998.*

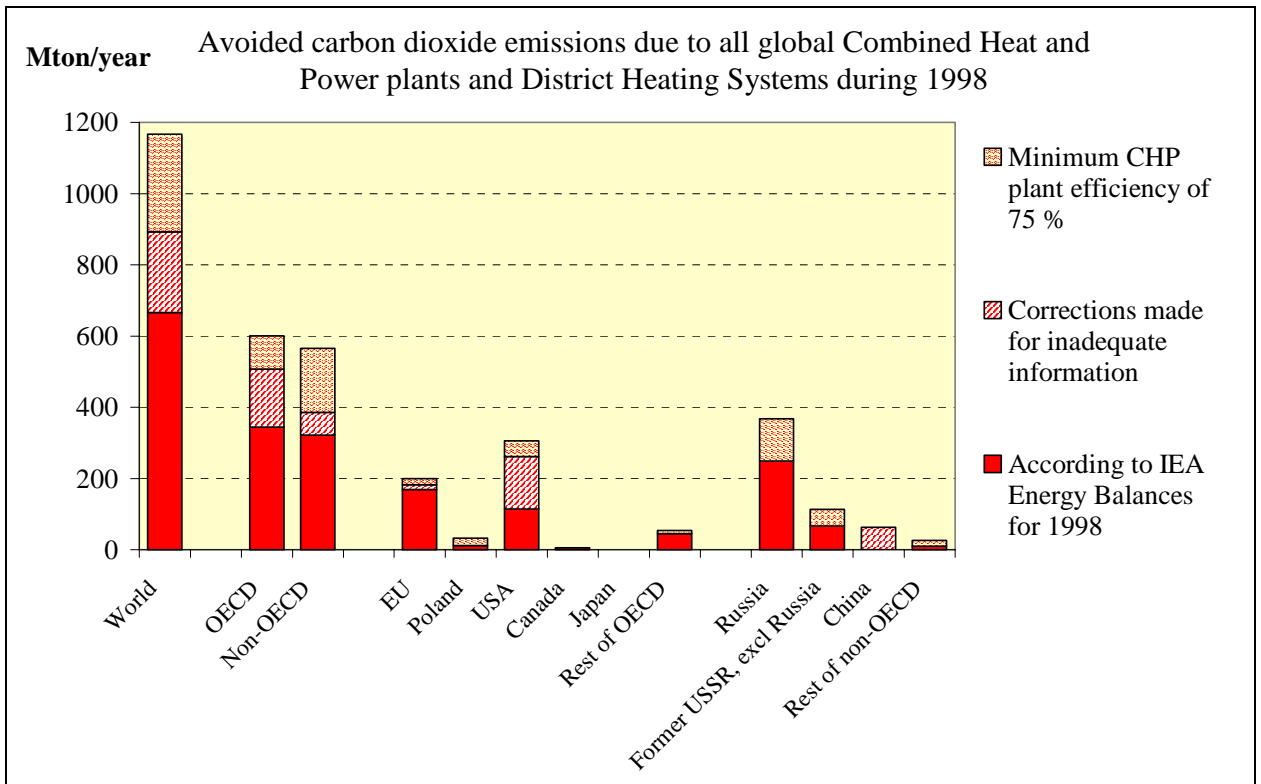
According to the original IEA Energy Balances for 1998						
Mton	CO2 emissions from DH/CHP plants	CO2 emissions replaced by electricity generated	CO2 emissions replaced by heat generated	Avoided CO2 emissions	Total CO2 emission in 1998	Relative reduction of CO2 from DH/CHP
World	2010	1753	924	<b>667</b>	22726	2,8%
OECD	751	921	175	<b>345</b>	12017	2,8%
Non-OECD	1259	832	749	<b>321</b>	9989	3,1%
EU	177	271	74	<b>169</b>	3171	5,0%
Poland	160	139	33	<b>12</b>	320	3,6%
USA	335	421	28	<b>114</b>	5410	2,1%
Canada	5	9	2	<b>6</b>	477	1,2%
Japan	1	-1	2	<b>0</b>	1128	0,0%
Rest of OECD	73	82	35	<b>45</b>	1511	2,9%
Russia	809	561	497	<b>249</b>	1416	14,9%
Former USSR, excl Russia	223	207	83	<b>67</b>	790	7,8%
China	142	0	137	<b>-5</b>	2893	-0,2%
Rest of non-OECD	85	64	32	<b>11</b>	4890	0,2%

***Table 2.** Calculation of avoided carbon dioxide emission due to DH/CHP plants with estimated corrections for inadequate information for the EU, USA and China.*

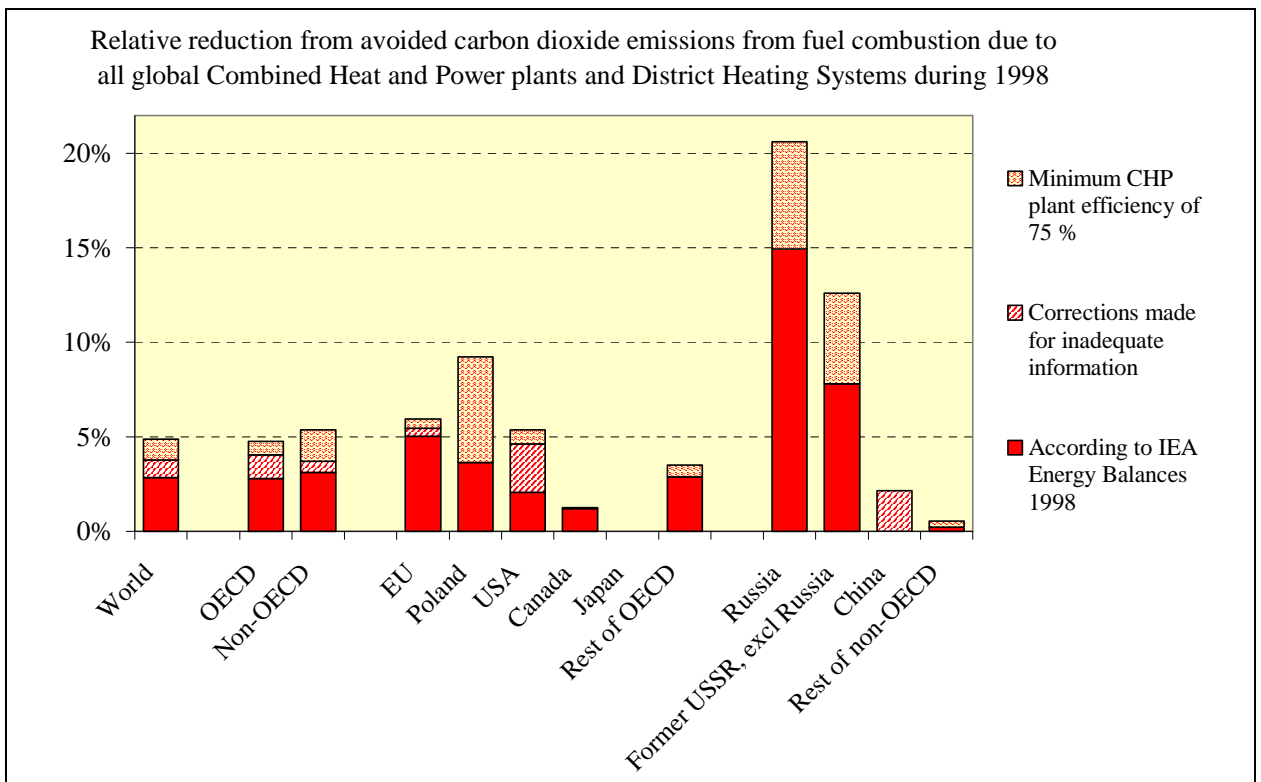
Corrections made for inadequate information in the IEA Energy Balances						
Mton	CO2 emissions from DH/CHP plants	CO2 emissions replaced by electricity generated	CO2 emissions replaced by heat generated	Avoided CO2 emissions	Total CO2 emission in 1998	Relative reduction of CO2 from DH/CHP
World	2136	1859	1169	<b>892</b>	22726	3,8%
OECD	834	921	421	<b>507</b>	12017	4,0%
Non-OECD	1302	938	749	<b>385</b>	9989	3,7%
EU	260	271	172	<b>182</b>	3171	5,4%
Poland	160	139	33	<b>12</b>	320	3,6%
USA	335	421	176	<b>262</b>	5410	4,6%
Canada	5	9	2	<b>6</b>	477	1,2%
Japan	1	-1	2	<b>0</b>	1128	0,0%
Rest of OECD	73	82	35	<b>45</b>	1511	2,9%
Russia	809	561	497	<b>249</b>	1416	14,9%
Former USSR, excl Russia	223	207	83	<b>67</b>	790	7,8%
China	185	106	137	<b>58</b>	2893	2,0%
Rest of non-OECD	85	64	32	<b>11</b>	4890	0,2%
				<b>Corrections made</b>		

A third set of estimations, assuming an overall conversion efficiency of 75 % for all CHP plants, is also included in **Figure 21** and **Figure 22**, showing the estimations made in volumes of carbon dioxide avoided and in relation to current carbon dioxide emission from fuel combustion.

The Euroheat & Power Committee of Ecology has in Euroheat 2001b estimated the avoided carbon dioxide emissions for the EU. Their estimation was 186 Mton for 1997. This value should be compared to the estimation for the EU in **Table 2**, which is 182 Mton for 1998.



**Figure 21.** Estimation of avoided emissions of carbon dioxide due to use of DH/CHP.



**Figure 22.** Relative reduction from avoided emissions of carbon dioxide due to DH/CHP.

## Conclusions

The major conclusion is that the avoided carbon dioxide emissions from the use of DH/CHP is significant and is about half of the magnitude of carbon dioxide reduction presumed in the Kyoto protocol.

Globally avoided carbon dioxide emission from DH/CHP can be increased by

- increasing the market penetration of central heat generation by introducing new and expanding existing district heating systems.
- increasing the heat utilisation in existing CHP plants by expanding the local heat sales.
- increasing the share of CHP in existing central heat generation, since only 48% is generated in existing CHP plants. The possibility is higher in non-OECD countries, since the share of CHP is 75 % in OECD countries.
- fuel substitution in existing DH/CHP plants, since coal constitutes 38% of fuel supplied.

Globally avoided carbon dioxide emission from DH/CHP will decrease when the carbon dioxide emissions from alternative generation of electricity and heat will be reduced. However, this is not a unique situation for DH/CHP; it will apply to all carbon lean technologies, since the future competition will not come from carbon rich technologies, but from other carbon lean technologies.

## Acknowledgement

This work has been financed by Annex VI of the IEA implementing agreement of District Heating and Cooling, including the integration of Combined Heat and Power, within the project *Promotion and Recognition of DHC and CHP Benefits in Greenhouse Gas Policy and Trading Programs*.

## Literature

China Statistical Yearbook 2000, no 19. Compiled by National Bureau of Statistics, People's Republic of China, China Statistical Press, Beijing 2000.

Euroheat & Power, District Heat in Europe 2001 Survey, Brussels 2001a.

Euroheat & Power, CO<sub>2</sub> reductions by Combined Heat and Power in the European Union. Brussels 2001b.

European Commission, Annual Energy Review 2000, Office for Official Publications of the European Communities, Luxembourg 2001.

Eurostat, Combined heat and power production (CHP) in the EU, Summary of statistics 1994-1998. Statistical Office of the European Communities, 2001.

Fachverband der Gas- und Wärmeversorgungsunternehmen Österreichs, Die situation der Fernwärme in Österreichs 1999. Euroheat & power – Fernwärme International 30(2001):11, 50-59.

International Energy Agency, CO<sub>2</sub> Emissions from Fuel Combustion 1971-1998, Paris 2000.

International Energy Agency, Energy Balances for OECD Countries 1998-1999, Paris 2001a.

International Energy Agency, Energy Balances for Non- OECD Countries 1998-1999, Paris 2001b.

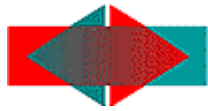
National statistics, Digest of United Kingdom Energy Statistics 2000. Department of Trade and Industry. London 2000. Available at [www.dti.gov.uk/epa/dukes](http://www.dti.gov.uk/epa/dukes)

US 1992 National Census for District Heating, Cooling and Cogeneration, Oak Ridge National Laboratory, July 1993.

Werner, S., Rewarding Energy Efficiency: The perspective of emissions trading. Euroheat & Power - Fernwärme International 30(2001):9, 14-21.

## **Appendix 4: Recommendations to the European Commission for the planned CHP Directive**

# **International Energy Agency Implementing Agreement on District Heating and Cooling, including the integration of CHP**



## **Recommendations to the European Commission for the planned CHP Directive**

**January 11, 2002**

## **Introduction**

The International Energy Agency Implementing Agreement on District Heating and Cooling, including the integration of CHP (IEA-DHC/CHP) applauds the European Commission's intention to develop and implement a directive on combined heat and power (CHP). The Implementing Agreement appreciates the opportunity to provide input prior to the preparation of a draft directive. Our recommendations are part of a project undertaken to promote and recognize the benefits of district heating and cooling DHC and CHP, particularly in the context of greenhouse gas (GHG) emissions trading and related energy and environmental policies.

Our comments address issues relevant to many types of CHP, but with a special emphasis on CHP implemented in conjunction with DHC systems. As noted in the Background Document, DHC has a significant role in current and future CHP. As part of the aforementioned project, the Implementing Agreement is in the process of developing an analysis of the global CO<sub>2</sub> reduction potential of DHC.

The Background Document summarizes the barriers to CHP, including economic, regulatory and institutional barriers. We believe that the CHP Directive must substantively address all three categories of barriers. We also recognize that many of these barriers are complex and can have different characteristics depending on the particular Member State. Thus, we do not expect that the Directive can solve all the barriers facing CHP. However, we believe that the Directive can and should incorporate strong measures designed to mitigate or eliminate the most critical barriers, and that with implementation of a strong Directive, CHP can fulfill its potential relative to increasing security of energy supply, reducing greenhouse gas emissions, and other policy objectives.

It is important that a broad and open consultation process be a key part of the development of the CHP Directive.

## **Urgency of Action**

We believe that the development and implementation of the CHP directive should be a high priority. The negative impact of barriers to CHP, particularly the impacts of energy market liberalisation, are significant and require timely action.

## **Internalisation of Environmental and Energy Security Benefits of CHP**

It is essential that steps be taken now to internalise the environmental and energy security benefits of CHP. The Background Document rightly points out that when a CO<sub>2</sub> emissions trading scheme is fully operational this will be an important step toward internalisation of environmental externalities. However, such a system will not be fully functioning until 2008 or later, and without action to address barriers the development of CHP potential will be seriously hampered. In addition, CO<sub>2</sub> trading will not address the other environmental benefits of CHP resulting from reductions in emissions of air pollution, nor will it provide recognition of the energy security benefits. The latter includes:

- increased fuel supply reliability resulting from the use of indigenous fuels like biomass or waste; strengthening of power grid reliability resulting from generation of CHP power near load centers; and
- reduction of power demand due to delivery and/or storage of heating or cooling energy through DHC systems.

Reduction in power transmission and distribution losses due to generation of power and/or reduction in power demand reduces power generation fuel consumption and the associated environmental impacts, as well as mitigating grid transmission and distribution constraints.

It is also important to recognize that with energy market liberalisation the focus on short-run economics and financial performance works against implementation of capital-intensive sustainable technologies such as DHC and CHP. The CHP Directive should be used to counteract this impact.

The most appropriate and feasible place to begin to address internalisation of CHP and DHC benefits is in tariffs and procedures governing interaction of CHP facilities with the power grid, as discussed below, and in energy and CO<sub>2</sub> taxation.

In countries such as Finland and Sweden, the present and suggested energy tax systems neglect the full environmental benefits of CHP. In these countries, heat from CHP plants is taxed as if the heat would have been produced in heat-only boilers. These taxation laws prevent the CHP industry from fulfilling its potential for improving the environment and energy security. The CHP Directive should encourage energy and CO<sub>2</sub> tax schemes that at the very least do not discriminate against CHP, and preferably would provide a positive incentive for CHP.

### **Grid System Issues**

There are a number of areas where treatment of CHP facilities must be improved to, at the very least, provide a level playing field and, in some areas provide an appropriate means of recognizing the environmental and energy security benefits discussed above:

- Guarantee of access to transmission and distribution systems;
- Technical standards for interconnection of CHP facilities to the grid;
- Bearing of costs relating to grid connection and grid reinforcement;
- Tariffs for sale of surplus power to the grid;
- Tariffs for use of grid to transport power to buyers; and
- Tariffs for purchase of back-up and top-up power.

The CHP Directive should require Member States to ensure CHP facilities access, under transparent and non-discriminatory terms, to the grid. A model interconnection standard would be a useful step. Technical standards and approval processes for interconnection should not be the burden they often are today. Limits should be established for grid connection cost per MegaWatt such that costs above this threshold are borne by the grid rather than the individual CHP facility. This would provide some recognition of the grid benefits of smaller CHP plants that supply power to the grid and/or reduce grid power demand but for whom the fixed costs of interconnection are a significant burden. We recommend this simple mechanism rather than complex, case-specific analysis of grid constraints.

Purchase by grid operators of surplus power from CHP facilities, and dispatch decisions, should incorporate an additional value for the environmental and energy security benefits of CHP and related DHC systems, including DHC-specific benefits as discussed below under “Definition and Certification.” This externality “adder” can be partially phased out as carbon trading and potentially other mechanisms begin functioning to effectively internalize environmental and energy security benefits.

Member States should ensure that tariffs for transmission and distribution services, and for back-up and top-up power, provided to CHP facilities and other distributed generators should be fair and non-discriminatory.

### **Gas Market Access**

The CHP Directive should ensure that CHP facilities do not face new barriers to accessing fuel. The potential for a threshold minimum consumption of gas (25 million cubic meters per year) for access to the liberalized gas market, raised in the Gas Directive, is a step in the wrong direction. The CHP Directive should correct the Gas Directive by eliminating the possibility that Member States can impose such a threshold.

### **Tradeable CHP Certificates**

The Tradeable Green Certificate (TGC) developed for renewable generation is a concept that can and should be applied to CHP. This is warranted by the clear environmental and energy security benefits of CHP. As has been determined in the context of CO<sub>2</sub> emissions trading discussions, making the certificates tradeable between Member States will increase economic efficiency. Following establishment of the EU total target and agreement regarding division of this target among Member States (as discussed below), the targets can be fulfilled through application of a system of tradeable certificates.

Project on Promotion and Recognition of DHC/CHP Benefits in Greenhouse Gas Policy and Trading Programs  
International Energy Agency Implementing Agreement on District Heating and Cooling, including the integration of CHP  
Swentiboldstraat 21, 6137 AE Sittard, P.O. Box 17, Netherlands  
Phone +31-46-420-2332, Fax +31-46-452-8260, E-mail M.Wobben@novem.nl Web home page www.iea-dhc.org

### **Definition and Certification**

The program for defining and certifying CHP must be consistent but provide flexibility for recognition of different types of CHP. The definition should be based on energy efficiency rather than emissions characteristics, because the latter approach tilts the system too aggressively toward gas. We need a diversity of fuels to promote energy security.

The UK Quality Assurance program provides a good model for development of an EU framework. This provides a reasonable approach to definition of a CHP quality threshold to qualify for special treatment (e.g., externality payments in grid supply power purchase, or for tradeable CHP certificates). A looser definition should be adopted for purposes related to CHP statistics. The UK QA program provides a reasonable initial framework for addressing the different types and sizes of CHP. However, additional provisions are needed to quantify additional benefits of DHC, for example:

- reduction in power demand and energy due to elimination of electric heating in individual buildings;
- reduction in power demand and energy due to substitution of CHP-heat-driven cooling for electric cooling; and
- reduction in power demand due to implementation of thermal energy storage in DHC systems.

### **National Targets**

The Commission's CHP Strategy set a goal of doubling CHP by 2010 from a base of 9% in 1994. Given the variety of national circumstances, achievement of this goal cannot be distributed equally. The CHP Directive should establish goals for each Member State that recognizes the current contribution as well as future potential of CHP. The targets should be binding, with flexibility introduced through a system of tradeable certificates as discussed below. A directive without any targets would not be strong enough to achieve the goals envisioned.

In addition to monitoring progress in meeting the CHP targets, the EU should monitor and report on progress toward fair and non-discriminatory interconnection guidelines on a country by country basis, and highlight findings regarding anti-competitive practices that restrict the implementation of CHP.



# Appendix 5: Response to the EU green paper on emissions trading

## Comments on “Green Paper on Greenhouse Gas Emissions Trading Within the European Union”

A Joint Position Paper by

International Energy Agency  
(Implementing Agreement on District Heating and Cooling Including Integration with  
Combined Heat and Power)  
and  
Euroheat & Power

September 4, 2000

The following comments address key questions posed in the Green Paper. To provide a context for these comments, we first summarize the importance of District Heating and Cooling (DHC) and Combined Heat and Power (CHP) in meeting greenhouse gas (GHG) emission goals for the European Union (EU).

### **Introduction**

DHC and CHP will be critical to meeting EU GHG reduction goals because they are carbon-lean technologies. We believe that a properly designed EU GHG emission trading system will help expand the use of these energy-efficient technologies. The EU trading system will be a key element supporting the development of an international emissions trading system.

The carbon reduction potential of DHC and CHP is large. An analysis by Euroheat & Power<sup>5</sup> has determined that without the existing DHC/CHP industry, EU carbon emissions would be 6% higher than today. Expanding DHC and doubling the share of CHP production, according to the Community goal, will further reduce EU carbon emissions 8% by 2010.

By linking energy users together, DHC systems connect energy users to sources of wasted energy, including power generation energy recovered through CHP. CHP is substantially more energy efficient than separate generation of electricity and thermal energy because heat that is normally wasted in conventional power generation is recovered. Compared to a conventional, electricity-only power plant at 30-40% efficiency, CHP plants can reach efficiencies of 80-90%. This fuel use reduction results in substantial reductions in emissions of GHG and air pollution.

DHC is important for implementing CHP because it expands the pool of potential users of recovered thermal energy. Low-temperature thermal loads—commercial and residential building heating and cooling—are served by DHC. Low-temperature thermal loads provide optimal CHP, with higher power output and efficiency compared with higher temperature loads often found in industrial CHP applications.

DHC also provides opportunities to productively use other sources of energy that are generally wasted, thereby eliminating fuel consumption and associated GHG emissions. Examples of these additional energy sources include:

- waste heat from industrial processes;
- energy from municipal waste or landfill gas;
- many forms of biomass; or
- heat contained in sewage effluent.

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<sup>5</sup> “Actual and future CO<sub>2</sub> reduction of district heating and combined heat and power in different Western and Eastern European countries,” by Hans Hof for the Committee for Ecology of Euroheat & Power, June 2000.

We welcome the Commission initiative on emissions trading and believe that establishment of a European system of emissions trading will provide important experience prior to the start of international trading in 2008.

## **Comments**

### *Scope of an EC emissions trading system*

*Question 1: Which sectors should be covered by emissions trading within the Community? Do the LCP and IPPC Directives offer a useful starting point for defining the sectoral coverage of a community emissions trading system?*

The approach recommended in the Green Paper relative to sectors covered is a good one, which will promote two important objectives: simplicity in the initial implementation, and sufficient liquidity for an effective market. With these objectives in mind, it is appropriate to focus on large point sources of carbon dioxide, and the Large Combustion Plant (LCP) directive provides a good starting point. Based on this directive, plants larger than 50 MW fuel input in key sectors, including electricity and heat production, would participate in the trading system.

This approach will mean that a significant portion of the district heating capacity in many countries will be included in the trading system. In Sweden, for example, over 60% of district heating capacity comes from plants with output capacity greater than 50 MW. However, in some countries this portion may be lower, and these countries may desire to expand the pool in the trading system to include district heating plants smaller than 50 MW. We believe that it is important to provide this type of flexibility to Member States. This is particularly important because most new district heating systems will be developed in smaller communities.

However, one implication of the focus on large point sources is potentially problematic for district heating. As a district heating system expands, its emissions will likely increase, requiring more carbon emission allowances and thus higher operating costs. Yet by expanding, and therefore eliminating multiple small emission sources that would otherwise supply heating energy for buildings, the district heating system creates substantial net environmental benefit. In order to avoid a competitive disadvantage that constrains this environmental benefit, it is critically important to ensure that strong European policies and measures in non-trading sectors will be applied.

Overall, we believe that the sectors suggested, and the thresholds based on the LCP directive, are an appropriate starting point for an emissions trading scheme. Clearly, the power production and district heating sectors are strongly interlinked in most countries and should be approached in an integrated manner. For the longer term, we agree with the statement on page 14: "Since economic gains from trading arise from differences in abatement costs between companies covered by the trading system, this would argue in favour of as wide and as varied a sectoral coverage as possible."

*Question 2: Should there be a common emissions trading scheme within the European Community for certain sectors in the interest of fair competition, maximum transparency and legal certainty for companies?*

Yes, a common scheme is appropriate due to growing integration of the power, gas and district heating sectors. A common emissions trading scheme is necessary for the power and gas sectors because integration of the electricity and gas markets in Europe is proceeding rapidly. Cross-border trade of emissions would be a necessary complement to cross-border trade of electricity and gas, and would lead to lower emissions and lower costs. The district heating sector is strongly related to the power sector (through CHP) and the gas sector (through fuel purchases) in all countries. Integration of district heating in a common scheme is necessary for fair competition and maximum transparency.

*Question 3: Would the flexibility offered by a co-ordinated scheme such as "opting-in"/"opting-out" be compatible with the requirements of the internal market, or would any advantages of such flexibility be outweighed by increased complexity?*

Yes, the advantages of such flexibility would be outweighed by increased complexity.

*Question 4: What scope is there for individual Member States to include more sectors in their domestic trading scheme than might be covered by a Community scheme?*

It is important that the Community scheme be implemented in as common and integrated a manner as possible. We assume that by “domestic trading scheme” the EC means the specific framework established in a Member State for trading within the integrated EU scheme by entities located within that State.

#### *Allocation of emission allowances*

*Question 5: Should the overall amount of allowances allocated to the trading sector in each Member State be subject to agreement at Community level?*

The amount of allowances allocated to the trading sector in each Member State should be determined by each Member State based on common principles and methodology established at the Community level.

*Question 6: Should the way in which allowances are allocated to individual companies be the subject of agreement at Community level? Or, do you consider detailed guidelines based on the state aid provisions and other rules of the Treaty to be sufficient to safeguard fair treatment?*

The allocation principle will be very important for DHC and CHP. Each method has its own advantages and disadvantages:

- With an allocation system based on past emissions (“grandfathering”) is not an appropriate allocation approach because it will tend to reward inefficient producers and penalize efficient ones.
- It would however be possible to grandfather based on benchmarking which establishes an amount of allowances per unit of output for each sector. For CHP plants the total useful energy output will include both electricity and thermal energy. With the benchmarking approach, a CHP plant, for example, should be allocated allowances for both its heat and power production.
- With an allocation system based on auction, fewer allowances will be needed for DHC and CHP compared to competitors using carbon-rich technologies. This is an appropriate approach for the long term, particularly if the funds collected are recycled in a way that rewards more efficient plants.
- It will be necessary to adjust the allocations in future compliance periods to reflect the mix of plants in operation. The most appropriate allocation system for the future must be based on emissions per unit of product output. In the energy sector, allowances should be allocated based on total useful energy output.

Grandfathering based on historical emissions is not acceptable to initiate the system. Grandfathering based on benchmarking is a better approach for initiating a trading system. In the long run, we believe that an allocation system based on emissions per unit of total useful energy output is the most appropriate approach because it will most efficiently reward the most environmental beneficial producers.

The principles for allocation of allowances should be the subject of agreement at Community level. The uniformity of allocation approach is not significant for DHC (which is not traded across borders) but it is important for CHP. A common allocation approach will ensure fair competition for CHP plants across borders.

It is also important that the allocation process rewards early action to reduce carbon emissions, or at least does not penalize early action.

#### *Synergy with other policies and measures*

*Question 7: Is it agreed that a balance has to exist between sectors engaged in emissions trading within the Community on the one hand, and non-trading policies and measures applied to other sectors on the other?*

It is very important for DHC that a balance exists between emissions trading and non-trading policies and measures. Systems representing the majority of DHC output will belong to the trading system, while building heating technologies will be covered by non-trading policies and

measures. If there is not a balance between the relative burdens of emission trading and domestic policies and measures, DHC will be at a competitive disadvantage when acquiring new customers. *Question 8: How can environmental effectiveness (in terms of fulfilling the Kyoto Protocol's commitments) and transparency be safeguarded using a mix of emissions trading, energy taxes and environmental agreements with targets based on energy efficiency per unit of output?* The experience from taxation of the European CHP industry suggests that a common carbon dioxide trading system will produce more emissions reductions at lower cost compared to many of the existing domestic energy tax systems. This conclusion is especially valid for Denmark, Finland and Sweden, where the present and suggested energy tax systems neglect the full environmental benefits of CHP. In these countries, heat from CHP plants is taxed as if the heat would have been produced in heat-only boilers. From a GHG perspective, these rules are absurd. Today, those taxation laws prevent the CHP industry from reducing existing carbon dioxide emissions.

Combining emissions trading and taxation could make sense only if the taxation scheme is strictly designed to benefit the environment, as opposed to raising government revenues.

We believe that emissions trading is a more effective, transparent and environmentally beneficial approach in the DHC sector compared to environmental agreements.

#### *Compliance and enforcement*

*Question 9: Are the currently available instruments (Monitoring Mechanism, infringement procedures) sufficient or should additional tools be developed in order for the Community to adequately assess compliance in the context of emissions trading within the Community?*

One monitoring and quantification issue that is of concern for DHC relates to future allocation of allowances for expanding DHC systems. Such expansion eliminates emissions from building boilers, and future allocations should account for this. Building boilers do not have the historical emissions data normally expected in order to meet the quantification standards for emissions trading. This does not mean that such emissions should not be credited in the allocation. Rather, a conservatively low estimate, based on fuel use or heat use and an assumed efficiency, can and should be used.

*Question 10: Do the elements of compliance and enforcement mentioned above warrant co-ordination or harmonisation at Community level, and which elements are more appropriately undertaken by Member States?*

Compliance and enforcement mechanisms should be strongly harmonized at the Community level.

# Appendix 6: Analysis of the emissions trading system in the UK.

## Introduction

This appendix sets out to determine the current use and prospects for CHP/DHC in the UK and explores how the UK Emissions Trading Scheme deals with DHC and CHP. In particular, this appendix addresses the scope of DHC and CHP projects that might benefit under the scheme and the quantification of GHG emission reduction realized. Finally, recommendations are made about how emissions trading schemes should treat DHC and CHP to realize the full GHG reduction potential that they offer.

## Current Use and Prospects for DHC/CHP in the UK

### *UK District Heating*

In 1998 approximately 250,000 dwellings in the UK were connected to district heating systems (around 0.25% of the national stock). In addition, around 175,000 occupants of multi-residential buildings are served by district heating. Fuels used in district heating amount to 41,300 GWh per year, of which 54% is gas, 20% fuel oil, 20% coal, 7% other and 2% waste. 41% of fuel use for district heating is in industrial buildings, 39% in hospitals, 10% housing and 10% education (CHPA website).

There is considerable potential for reducing carbon emissions from UK district heating systems. Fewer than 5% of district heating schemes have CHP, only half have thermostatic controls and only 30% have time control. In 80% of cases there is no alternative method for heating hot water in the summer, resulting in inefficient operation, particularly where there are single boilers. Heat is rarely metered and pipework is typically 20 years old and has not been refurbished.

### *UK Combined Heat and Power (CHP)*

In the UK a total of 4,630 MWe of good quality<sup>6</sup> CHP capacity was installed at the end of 2000 (DTI 2002). In addition, consent has been given for schemes totalling 2,719 MWe capacity. As gas prices have risen whilst electricity prices have fallen, many of these schemes may not proceed at present.

It is estimated that the economic potential for CHP is currently between 12,000 and 20,000 MWe, depending on the range of future energy prices, rates of return on capital expected in industry and other factors<sup>7</sup>. This compares to the UK Government's stated target of 10,000 MWe CHP capacity by 2010<sup>8</sup>.

Two thirds of new CHP capacity is now installed under energy service arrangements in the UK and this is expected to rise to around 90% in the future. About 1/3 of electricity generated by CHP is exported to other users or local public electricity suppliers. This increase has been brought about by market liberalisation and is evidenced by the increase in the power to heat ratio in more recent schemes.

### *Initiatives Influencing CHP Installations in the UK*

The UK's Climate Change Programme (DETR 2000) cites CHP as a key element in its climate change strategy for the business, domestic and public sectors and sets a target of achieving an installed capacity of at least 10,000 MWe by 2010<sup>9</sup>. The Community Energy Programme, announced in April 2001, is one action that supports this aim. It is a £50M grant programme available to install new schemes and refurbish obsolete infrastructure and equipment with £20M available in 2002/2003. This aims to increase the development and installation of community

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<sup>6</sup> As determined by the Combined Heat and Power Quality Assurance Scheme (described later).

<sup>7</sup> Forthcoming study of CHP potential for DEFRA, UK Government Department for the Environment, Food and Rural Affairs.

<sup>8</sup> Climate Change – the UK Programme DETR, UK Government Department for the Environment, Transport and the Regions, November 2000.

<sup>9</sup> This represents an approximate doubling of the current capacity.

heating schemes by addressing two key barriers: a lack of investment capital and a lack of knowledge on how to deliver the benefits of community heating.

There are a number of other recent initiatives aimed at encouraging the installation of CHP plants in the UK:

- CHP that is certified as being of good quality under the Government's CHPQA programme is eligible for a number of fiscal benefits. For good quality CHP schemes, both fuel use and electricity generated (whether it is used on site or exported) are exempted from the Climate Change Levy<sup>10</sup>.
- Enhanced Capital Allowances can be claimed for investment in good quality CHP schemes.
- Plant and machinery for power generation for CHP schemes have now been made exempt from business rates, which puts them on an equal footing with power generators, who are also exempt from business rates.
- New guidelines for power station developers seeking consent to build new power generation capacity from the UK government require opportunities for supplying heat as well and generating electricity be considered.

The above factors all provide a boost for those seeking to build new CHP plant and enhance DHC in the UK.

Mitigating factors include concern amongst small generators that the new electricity trading arrangements (NETA) that were introduced in March 2001 to increase competition in the wholesale market will impact unfavourably on them<sup>11</sup>. A report by OFGEM (Office for Gas and Electricity Markets) in February 2002 has made recommendations to alter the trading rules to develop consolidation services to bundle together small unpredictable demands to provide more predictable electricity supply and greater access to the wholesale electricity market.

Moreover, recent large increases in gas prices and falling electricity prices mean that many schemes that have been given consent to build may not be economic under current market conditions.

#### *Quality Assurance for Combined Heat and Power (CHPQA)*

This is a methodology that has been developed to determine if CHP schemes in the UK qualify as "Good Quality CHP" and can be applied to all or part of the inputs, outputs and capacity of a CHP scheme (DEFRA 2000).

For the purposes of the CHPQA, a CHP scheme may consist of a number of prime movers connected in series or parallel. Prime movers connected in series must be considered as part of a single scheme but where they are connected in parallel they can be considered as part of a single CHP scheme or considered as separate CHP schemes. Associated auxiliary or back up boilers may also be included within the scheme boundary.

Certification issued under the CHPQA programme can be used to determine eligibility for fiscal or other benefits, notably enhanced capital allowances, and exclusion from the Climate Change Levy.

In essence, the scheme determines a Quality Index (QI), which provides a measure of the energy efficiency of the CHP scheme compared to alternative sources of heat and power. Standard coefficients are used to represent the efficiency of alternative heat and power sources and the power coefficient varies with the size of the power plant. Additional coefficients are provided for special cases (fuel cell schemes, reciprocating engine schemes, existing steam turbine and reciprocating steam engine schemes and alternative fuel schemes).

The definition of QI is

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<sup>10</sup> The Climate Change Levy was introduced in April 2001 and is applied at the rate of 0.43p/kWh for electricity and 0.13p/kWh for gas (around 10% of the fuel cost)

<sup>11</sup> The original arrangements did not permit small generators to sell fixed amounts of electricity and unpredictable output separately.

$$QI = (X * \eta_{elec}) + (Y * \eta_{heat})$$

Where

- X = coefficient for alternative power supply
- $\eta_{elec}$  = power output from CHP/fuel input to CHP
- Y = coefficient for alternative heat supply
- $\eta_{heat}$  = “useful” heat from CHP<sup>12</sup>/fuel input to CHP

The threshold criteria for good quality CHP may defined in terms of

Fuel inputs;

$\eta_{power} \geq 20\%$  (15% for existing steam turbines until 1 April 2005).

Power output;

$QI \geq 100$  over a calendar year.

In the first year of operation of a Scheme a  $QI \geq 95$  will qualify.

For residential community heating this may be over the heating season.

Power generation capacity;

$QI \geq 100$  at maximum heat output under normal operating conditions. Where the maximum heat output is maintained for the following cumulative periods:

1,000 hours for industrial, commercial or institutional schemes,

750 hours for mixed schemes where residential use  $\geq 10\%$ , and

500 hours for residential schemes.

Around 90% of CHP capacity in the UK has been registered under the CHPQA scheme, and those which have not registered are largely in sectors where the fiscal benefits do not apply.

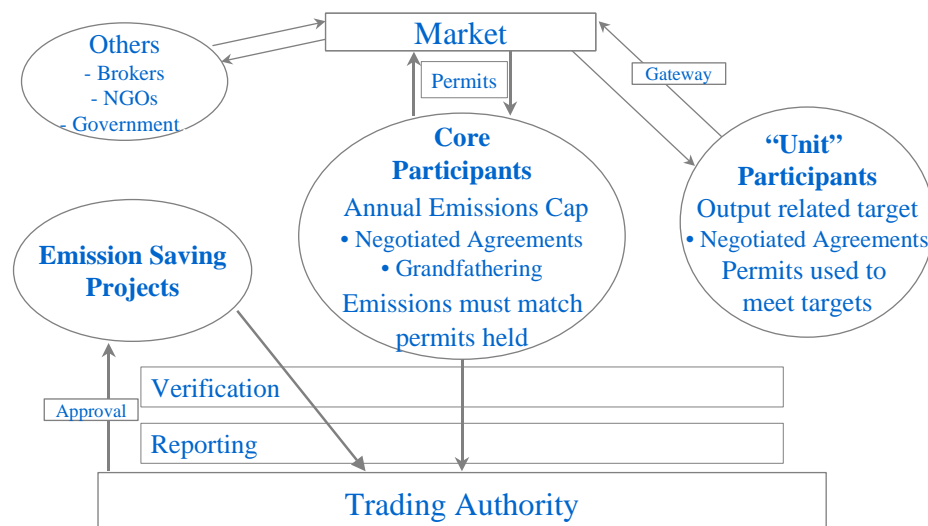
### **Current status of the UK Emissions Trading Scheme**

Details of the UK Emissions Trading Scheme and guidance on reporting emissions were published in 2001 (DEFRA Aug 2001) as a “Framework for the UK Emission Trading Scheme” together with “Guidelines for the Measurement and Reporting of Emissions in the UK Emissions Trading Scheme” More recently, legal rules of the Scheme were published. All these documents are available on the UK Department of the Environment, Food and Rural Affairs web site (DEFRA web site).

The scheme is a voluntary cap and trade scheme and the UK government are offering incentives worth £215M over five years to those who become direct participants in the scheme and take on an absolute emission reduction target. The reduction targets based on a percentage reduction in emissions compared to a baseline determined from emissions for the 3 years up to and including 2000<sup>13</sup>. All emission sources under management control will be eligible for inclusion, and all emission sources must be included, although it will be possible for participants to enter only sources in particular (industrial) sectors. In addition to direct participants, the scheme also makes provision for approved carbon reduction projects in the UK to generate tradable carbon credits. The detailed rules concerning the determination of baselines and the types of project that will be eligible have not yet been finalised.

<sup>12</sup> Where the heat supplied by CHP Scheme must be used in a manner that demonstrably displaces heat that would otherwise be supplied from other energy sources.

<sup>13</sup> It will be possible to use baseline based just on 2000 emission levels where past data is not available.



### A schematic showing the overall structure of the UK Emissions Trading Scheme

In all there are four ways of participating in the Scheme:

- Take on a voluntary emissions target in return for a financial incentive
- Via an existing energy target set under the Negotiated Agreement
- Via an approved emission reduction project
- By opening a trading account.

#### *Direct participants*

Companies, groups of companies and public sector organisations are eligible to join the Emissions Trading Scheme as direct participants, providing they have no prior obligation to reduce emissions. But emissions from households are not eligible for the financial incentives. The rules for direct participants are well defined and the first bid compliance period began on 1 January 2002.

The auction for entry into the UK emissions trading scheme took place from 11th March to 12th March 2002 and was completed successfully after 9 rounds. The auction cleared at a price of £53.37, which is the price the Government will pay per tonne of emission reduction delivered by organisations. The figure of £53.37 is per annual tonne of CO<sub>2</sub> equivalent, and hence will be three times lower when due to cumulative savings over the 5 year period. This equates to about US\$25 per tonne at current exchange rates. However, this figure bears no relation to the price of carbon that emerge from the UK Emissions Trading Scheme, and should be compared to costs of alternative policy actions for reducing carbon emissions.<sup>14</sup> 34 organisations won the auction at this price, taking on binding emission reduction targets totalling 4.0 million tonnes of CO<sub>2</sub> equivalent (tCO<sub>2</sub>e) by the end of the five years of the scheme. This was approximately an 11% average emission reduction from organisations' baselines.

Emissions targets will include both direct emissions and indirect emissions, such as those from grid electricity, over which the participant has management control<sup>15</sup>. Hence, installing CHP will become more attractive to participants as it could help reduce their emission levels so that they reach their target. Similarly, importing electricity or heat from a CHP scheme will also be more attractive where emissions are lower. Here there will be an additional onus on the participant to have the lower emission heat and power verified, although the introduction of the CHPQA will mean that much of the information required will be readily available.

<sup>14</sup> These typical range from around £20 - £200 per annual tonne of CO<sub>2</sub>.

<sup>15</sup> Where management control over an emission source is defined as "...when it exercises dominant influence.....through having an ability to direct the financial and operating policies governing the emissions source."



As noted earlier, the majority of CHP capacity in the UK is installed under energy service arrangements. It is unlikely that it will be beneficial for many of these companies to become direct participants in the Emissions Trading Scheme, as reducing gross emissions will generally fly in the face of expanding their business. Only where CHP energy service companies that have substantial opportunities to switch to lower carbon fuels could benefit from direct participation. The project route provides a way into the scheme, for new DHC/CHP installations in particular. However, compared to direct participation the project route has much greater uncertainty about the incentive offered by the Scheme as it depends entirely on the market price of carbon emissions. Furthermore the UK Emissions Trading Scheme specifically excludes the electricity supply industry from becoming direct participants in the scheme<sup>16</sup>. This decision arose primarily because there are already significant obligations on electricity suppliers to reduce carbon emissions, in particular, the Renewables Obligation, which requires suppliers to source 10% of their electricity from renewables by 2010, and the Energy Efficiency Commitments, which requires electricity and gas suppliers to achieve targets for the promotion of improvements in domestic energy efficiency.

#### *Carbon Savings from CHP*

The following (selected) emission factors are to be used in the Scheme to determine energy related CO<sub>2</sub> emissions.

<b>Energy/Fuel</b>	<b>Emission Factor kgCO<sub>2</sub>/kWh</b>
Electricity <sup>17</sup>	0.43
Natural Gas	0.19
Gas/Diesel Oil	0.25
Petrol	0.24
Heavy Fuel Oil	0.26
Coal	0.30
LPG	0.21
Renewables <sup>18</sup>	0.00

The scheme also deals with assigning emissions from CHP between heat and power by assuming that heat is generated at twice the efficiency of electricity generation.

$$C_e = \frac{2 * \text{total CO}_2 \text{ emitted}}{2 * \text{electricity generated} + \text{heat output}}$$

$$C_h = \frac{\text{total CO}_2 \text{ emitted}}{2 * \text{electricity generated} + \text{heat output}}$$

Where

C<sub>e</sub> = carbon emission factor for power

C<sub>h</sub> = carbon emission factor for heat

The key thing here is the relationship between the emission factor for heat and power from CHP and the emission factor for alternatively sourced products. As the emission factor for electricity is around twice the emission factor for heat produced from natural gas (the lowest fossil alternative) this allocation seems reasonable at first glance. The detailed analysis in a later section highlights the problem of using a fixed factor to allocate emissions between products.

<sup>16</sup> Apart from usage of electricity in their own headquarters or other similar uses, or by taking responsibility for emissions from other sources.

<sup>17</sup> This fixed factor is to be used for all years and applies to all electricity supplied from the public supply network (except for eligible renewable sources).

<sup>18</sup> Heat and power (provided it is not part of the renewable electricity obligation on electricity suppliers) generated from the following sources are designated a zero emission factor under the Scheme: wind energy, hydro power (excluding plants > 10MW), tidal power, wave energy, photovoltaics, photoconversion, geothermal hot dry rocks, geothermal aquifers, municipal and industrial wastes, landfill gas, agriculture and forestry wastes, and energy crops.

## *Carbon Credit Projects*

Overall, the facility for carrying out projects to generate carbon credits appears to be a more promising route for DHC and CHP to benefit from Emissions Trading.

Guidance for project developers is still under consideration, and CHP and heat production is one of the five sectors where guidelines for establishing bottom-up baselines is considered as a high priority by UK Government. For all projects general criteria relating to additionality<sup>19</sup> and environmental benefits will need to be met and must be approved by the Emissions Trading Authority.

In developing project specific greenhouse gas emissions baselines for ETS projects the key issues are:

- Project and baseline boundaries (including leakage and outsourcing)
- Baseline evaluation
- Duration of baseline
- Data sources and integrity

Projects which result in avoided emissions elsewhere, as well as those which result in a direct reduction in emissions, will be eligible. Avoided emissions will need to be calculated by comparison to an alternative scenario and it will be necessary to demonstrate that the operational characteristics are realistic for the proposed technology. The actual annual emissions will be calculated using the same methodology as the Emission Measurement and Reporting protocols (DFRA March 2001).

The baseline will need to be fixed for the life of the project or altered periodically but will not be retrospectively altered.

### **Lessons from the UK Emissions Trading Scheme on the Treatment of DHC and CHP**

There are several essential elements for estimating GHG emissions impacts from DHC and CHP. These are:

- the DHC/CHP scheme boundary,
- the emissions factor used for heat and power displaced,
- the time period under consideration, and
- the allocation of emissions between heat and power

By examining these in the light of the UK Emissions Trading Scheme it is possible to see where provision for DHC and CHP is inadequate.

For direct participation in the Emissions Trading Scheme the role that DHC and CHP can play is restricted by the exclusion of domestic emissions from the scheme<sup>20</sup>. Although provision is made for dealing with company participants who want to export or import heat and/or power, the additional work involved in verifying emissions from imported heat and power will act as a barrier.

One solution would be to permit all electricity and/or heat suppliers to take on relative emission reduction targets (in terms of kg CO<sub>2</sub>/kWh generated etc.). This is at least partially compatible with the current scheme that uses a fixed emission factor for public supply electricity. This would result in responsibility for reducing demand for electricity resting with the user, whilst the generator remains responsible for the carbon intensity (but not the quantity) of the electricity it generates. Whilst this will generate an element of double counting as a 10% reduction in demand coupled with a 10% reduction in carbon intensity will only result in a 19% reduction in absolute carbon emissions. This relatively small uncertainty could be dealt with by applying appropriate factors to counteract the double counting.

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<sup>19</sup> Emission reductions must also be in excess of those required to meet environmental regulations or other obligations.

<sup>20</sup> In certain circumstances projects for reducing household emissions are eligible. These projects have to be carried out by, or in conjunction with, an electricity or gas supplier that has an obligation under the Energy Efficiency Commitment (which applies to major electricity generators in the UK).

There is good provision for DHC/CHP in the projects facility. However, this is likely to benefit only large new schemes as the amount of information required to define and verify a baseline emission level and to report and verify actual emission levels will present a significant burden. This situation could be significantly improved, however, if effective guidelines could be developed that provide a fast and effective route for getting approval from the Emission Trading Scheme that is integrated with the CHPQA.

The emission factor used for public supply electricity is 0.43kgCO<sub>2</sub>/kWh, which represents an average system emission factor for the three years to 2000. However, in reality, reductions in electricity demand (whether they are brought about by using electricity from alternative generation sources or by reducing demand) result in a reduction in carbon emissions at the margin. For the UK the marginal emission factor for public supply electricity is, on average around 70% higher than the system average.<sup>21</sup> Hence it can be argued that using the system average will substantially underestimate the savings that can be realised.

When looking at new CHP capacity there is an argument for comparing emissions savings against a baseline from the new electricity generation plant avoided. In the UK this currently puts CHP up against combined cycle gas generation plants, which have an emission factor similar to the 1998 - 2000 system average.

However, the UK electricity generation mix is projected to alter in the future, and combined cycle gas generation may become the marginal plant within a decade.

Clearly the situation in other countries will be very different, and appropriate emission factors for electricity generation avoided will be required. Standard emission factors for heat generation avoided may also be needed. Provided these are constructed on the same basis for each country, international emissions trading arrangements and JI and CDM projects should result in CHP projects preferentially undertaken in countries where more substantial emission reductions result.

### **Analyses Demonstrating the Application of the UK Emissions Trading Scheme to Specific DHC/CHP Situations**

The results of the following analyses are applicable to both direct participant and project based DHC/CHP. However, for direct participants the boundaries will be restricted to on-site use of heat and/or power, and emission reduction associated with exported heat and power will not count towards the emissions target.

The effect of applying the ETS rules are explored using the same seven examples of CHP plant that were used for the analysis carried out in section on Trading Scheme design issues. Appendix 7 gives a more detailed technical description of these technologies

- A Small (5.2 MWe) gas-fired reciprocating engine.
- B Small (10.7 MWe) simple cycle gas turbine.
- C Medium (27.8 MWe) combined cycle gas turbine.
- D Large (102.8 MWe) combined cycle gas turbine
- E Medium (30.4 MWe) coal-fired steam turbine.
- F Large (93.6 MWe) coal-fired steam turbine
- G Medium (30.4 MWe) biomass-fired steam turbine.

The overall efficiency and heat:power output ratios of the four CHP units are shown in the table below:

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<sup>21</sup> BRE estimate.

Code	Type	heat:power	Overall efficiency
A	Small engine (95% gas 5% oil)	1.5	80%
B	Small gas turbine simple cycle	1.65	86%
C	Medium gas turbine combined cycle	0.9	85%
D	Large gas turbine combined cycle	0.83	85%
E	Medium steam turbine coal-fired	2.28	87%
F	Large steam turbine coal-fired	1.95	89%
G	Medium steam turbine biomass-fired	2.32	88%

Calculations are made of the percentage carbon reduction achieved if the CHP unit in question replaced:

- Gas-fired heating with a seasonal efficiency of 75%
- Grid electricity using the emission factor in the UK Emissions Trading Scheme measurement and reporting protocol of 0.12kgC/kWh

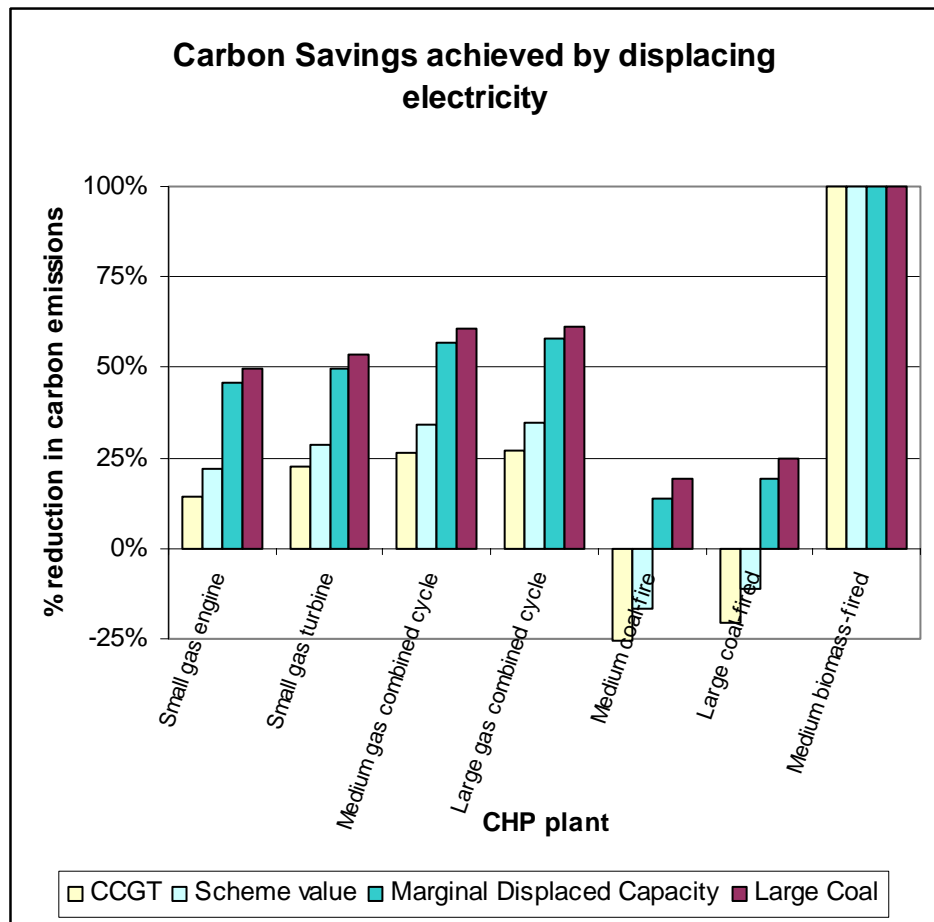
The resulting carbon reductions are summarised in the following table.

Code	Type	% reduction in emissions
A	Small engine (95% gas 5% oil)	22%
B	Small gas turbine simple cycle	29%
C	Medium gas turbine combined cycle	34%
D	Large gas turbine combined cycle	35%
E	Medium steam turbine coal-fired	-17%
F	Large steam turbine coal-fired	-11%
G	Medium steam turbine biomass-fired	100%
Emission Factor (kgC/kWh)		0.21

It is clear that all the gas fired CHP units would result in a net reduction in emissions, whilst the coal-fired units result in small net increase in emissions. As biofuels are renewable and are designated with zero emissions in the UK Emissions Trading Scheme, the biomass-fired plant results in 100% reduction in emissions.

#### *Alternative Emission Factors for Grid Electricity*

For comparison, the savings that would be realised if alternative emission factors were used have also been calculated. These are summarised graphically below:



In the UK the Scheme value of 0.12 kgC/kWh is based on the system average value for the years 1998-2000, which is close to the emission factor for power generated by a new combined cycle gas turbine with an efficiency of 49%. However, in the UK it is coal fired power stations more frequently operate at the margin. An analysis of marginal generation plant in the UK determined an emission factor for offsetting an additional 3 GW of grid electricity for 14 hours a day. This gave an emission factor of 0.21 kgC/kWh for displaced grid electricity in the UK, a value that is closer to that of large coal-fired power stations.

Using a more appropriate emissions factor for grid electricity displaced result in a substantial increase in the emission reductions for gas-fired plant and recognised the emission reduction that coal-fired CHP plants can make.

#### *Imports of Heat and Power*

The application of the Emissions Trading Scheme reporting protocol for imports/exports derived from CHP is explored here. The protocol effectively reallocates carbon emissions from CHP between electricity and heat in a 2:1 ratio.

Allocating carbon emissions to heat and power using the Scheme rules for the same example CHP units as previously discussed shows that this arbitrary reallocation can lead to carbon savings being skewed towards one product. The table below shows the effect of applying the reallocation formula. Results are shown for both the Scheme value for displaced electricity and for the more realistic emission factor for marginal displaced capacity. When the Scheme emission factor for electricity is used, the percentage emission reduction attributed to heat is greater than for power in all cases.

Using the marginal displaced capacity emission factor with the Scheme's heat and power allocation method would result in percentage emission reductions attributed to power being greater than those for heat in all instances. Here, in the case of the coal-fired units, the UK Emissions Trading Scheme methodology would allocate a net increase in emissions to the heat produced, even though the CHP units result in a net reduction in carbon emissions.

% reduction in emissions		Scheme value			Marginal Displaced Capacity		
Code	Type	Heat	Power	Heat & Power	Heat	Power	Heat & Power
A	Small engine (95% gas 5% oil)	26%	19%	22%	26%	54%	46%
B	Small gas turbine simple cycle	33%	26%	29%	33%	58%	50%
C	Medium gas turbine combined cycle	38%	32%	34%	38%	62%	57%
D	Large gas turbine combined cycle	39%	33%	35%	39%	63%	58%
E	Medium steam turbine coal-fired	-12%	-23%	-17%	-12%	31%	14%
F	Large steam turbine coal-fired	-6%	-17%	-11%	-6%	35%	19%
G	Medium steam turbine biomass-fired	100%	100%	100%	100%	100%	100%
Emission Factor (kgC/kWh)		0.12	0.12	0.12	0.21	0.21	0.21

A more desirable outcome would be for a similar level of carbon savings to be attributed to both products. A formula for achieving this is suggested in the next section.

Where both heat and power are used by a company/entity that is generating them the issue of allocation between products does not even arise. However, were a Scheme participant to export one CHP product to a non-Scheme participant they could find themselves with a net increase in emissions even though the CHP plant results in a net reduction in emissions.

Alternatives to an arbitrary allocation of carbon emissions between CHP products are available. One common practice is to assume carbon emissions associated with one product, typically heat, are the same as that from the alternative supply. Hence any emission reductions are assigned to the other product, usually electricity.

Arguments have been put forward for assigning emissions from the simultaneous generation of heat and power to the lead product, i.e., the one which determines when the plant runs or when output is changed (van dan Berg and Orchard, 1998). Whilst at the extremes this approach is logical (e.g., for a power plant that is run to generate electricity and where waste heat can be used when available, all emissions are assigned to electricity), for practical purposes it is difficult to devise a defensible way to determine if a plant is heat-led or power-led during usual operating conditions. Furthermore, the allocation of emissions at a particular point in time is dependent on the operational history of the plant.

Allocation of emissions to effectively share the emission reduction between the products would seem to offer a better solution as it avoids one CHP product being given a larger emissions burden than the overall emission efficiency indicates. A formula for achieving this is suggested in the next section of the appendix.

### **Suggestions for better recognising emission reductions from DHC/CHP in Emissions Trading Schemes**

The UK Emissions Trading Scheme recognizes the benefits of DHC and CHP in some instances. However, there are many circumstances where the emission reduction benefits of DHC and/or CHP are not fully recognized.

Scheme rules that may result in emission reductions not being included in the scheme are listed below:

1. No credit for early action - baseline is determined by previous emissions (grandfathering).
2. The domestic sector is excluded from the Scheme.
3. The electricity supply industry is not currently eligible to join the Scheme.
4. Participation at the company/entity level combined with a source-based approach to emissions does not favour expansion of existing schemes.
5. The Scheme emission factor for grid supply electricity does not fully reflect the reduction in emissions brought about by decreases in demand.
6. The rule for allocating emissions between heat and power can allocate an unfair emissions burden to one product.

7. Scheme participants can only include emissions arising from the consumption of combustion products (heat or power) on site.
8. There is no provision for the verification of emissions from imports of heat or power where supplies are not metered, hence such emission will be effectively excluded for Scheme participants.

To some extent the project facility will address some of these issues, particularly for points 6,7 and 8 which are essentially issues connected to the boundary for Scheme participants.

Suggestions as to how the current Scheme rules could be adjusted to better recognise the potential for emissions reduction are given below:

1. The setting of targets based on benchmark emissions for electricity and other energy services would have the effect of giving stiffer targets to those with the greater potential to reduce emissions, and would not penalise more efficient/lower plant. However, in a voluntary scheme this would have the effect of dissuading those with the greatest potential from joining.
2. Allow emissions from energy supply services from DHC/CHP to the domestic sector to be included by Scheme participants.
3. Admit electricity (and possibly other energy service) supply companies to the scheme with output-based emission reduction targets e.g., set in terms of kgCO<sub>2</sub>/kWh, for all on site combustion. This would recognise the benefits of all efficiency and carbon reductions on the supply side regardless of whether a particular supplier is increasing or decreasing output. Reductions in the demand for energy services could still be recognised using a fixed factor by the end user. Whilst this would effectively result in some double counting, this could be reconciled by applying an adjustment to either or both the end use and supply targets. The additional uncertainty that this creates is small compared to those associated with setting baseline emission levels.
4. The current rules (which allow targets to be effectively adjusted to take account of the addition or removal of emission sources) could be extended to account for changes in the output of heat and/or power from an emissions source.
5. Use of an emission factor for grid supply electricity that better reflects the observed changes in emissions with demand would result in improved recognition for DHC/CHP emission reductions. For the UK this would currently result in the emission factor for grid supply electricity almost doubling.
6. An alternative formula for reallocating emissions between heat and power is as follows:

$$C_e = C_{alte} * \frac{C_f * F}{C_{alte} * E + C_{alth} * H}$$

**Where:**

- C<sub>e</sub> = emission factor for electricity
- C<sub>h</sub> = emission factor for heat
- C<sub>f</sub> = emission factor for CHP fuel
- C<sub>alte</sub> = emission factor for alternative electricity supply
- C<sub>alth</sub> = emission factor for alternative heat supply
- H = heat output
- E = electricity output
- F = fuel input

This results in emissions savings being equally divided between CHP products. While this approach does require knowledge of the emission factor for alternative heat supply to be defined within the Scheme, an emission factor for alternative electricity supply is already defined in the Scheme and, in principle, defining an emission factor for typical alternative heat sources is no different.

7. Scheme participants could be permitted to include emissions arising from the consumption of combustion products off-site, where it can be proved that the recipient is either not participating in the Scheme or is not including emissions from the

important products in its source list. In instances where emissions are exported to sectors that are ineligible, or not participating in the Scheme, e.g., the domestic sector and the electricity supply industry, emissions from the consumption of combustion products off-site could be included.

8. Where exported heat or power is unmetered it would be impossible for the emissions arising from its use to be included by the importer, as the quantity could not be verified. Hence it would be appropriate for the exporter to include the emissions as their own in this instance.

## **Conclusion**

Ideally, emissions trading should benefit DHC/CHP wherever it results in a net reduction in emissions. The UK Greenhouse Gas Emissions Scheme is only partially successful in this. Specifically, the Scheme does not fully recognise the benefits of DHC/CHP because:

- It does not give a realistic assessment of emissions from alternative power generation.
- The rules concerning the boundaries for the inclusion/exclusion of emissions for direct participants, combined with the partial/voluntary nature of the scheme, means that emission reductions associated with heat or power consumed outside a company boundary are excluded.

The project mechanism potentially provides a means of overcoming the second of these points as project boundaries can be defined in a more flexible manner.

An additional benefit of DHC/CHP is more flexibility to switch to lower-emissions generation options (compared to alternative conventional supplies) in the future. Such potential is not accounted for in emissions trading, but could play a significant role in reducing emission levels in the future.

## **References**

Combined Heat and Power Association (CHPA), <http://www.chpa.co.uk>

UK Government Department for Trade and Industry (DTI), Digest of United Kingdom Energy Statistics 2001, The Stationary Office, 2002.

UK Department for the Environment, Transport and the Regions (DETR) Climate Change: The UK Programme, DETR, The Stationary Office, November 2000.

UK Government Department for the Environment, Food and Rural Affairs (DEFRA), Combined Heat and Power Association CHPQA: A Quality Assurance for Combined Heat and Power – The CHPQA Standard Issue 1, November 2000.

UK Government Department for the Environment, Food and Rural Affairs (DEFRA) Framework for the UK Emission Trading Scheme, August 2001.

UK Department for the Environment, Food and Rural Affairs (DEFRA)  
<http://www.defra.gov.uk/environment/climatechange/trading/index.htm>

UK Department for the Environment, Transport and the Regions (DEFRA) Guidelines for the Measurement and Reporting of Emissions in the UK Emissions Trading Scheme, 16th March 2001.

K. van den Berg, W R H Orchard, The Economics of the Heat Supply Sector: Main distortions; the importance of proper cost-allocation for heat and power to meet Kyoto Targets, report for EC Phare Multicountry Energy Project: ZZ 9511.02.02, 1998.



## Appendix 7: CHP and Conventional Technology Emissions Calculations

### CHP

		Small gas turbine simple cycle	Medium gas turbine combined cycle	Large gas turbine combined cycle	Medium steam turbine coal-fired	Large steam turbine coal-fired	Medium steam turbine biomass-fired	medium steam turbine biomass-fired (zero factor)
<b>Technology</b>	<b>Small engine</b>							
Capacity (Mwe)	5.17	10.69	27.77	102.80	30.35	93.56	30.35	30.35
Fuel mix	95/5% gas/oil	Gas	Gas	Gas	Coal	Coal	Biomass	Biomass
<b>Fuel input</b>								
Fuel input (LHV) MW	16.18	32.90	61.94	220.88	114.71	309.76	114.71	114.71
<b>Energy outputs (MW)</b>								
Electric	5.2	10.7	27.8	102.8	30.4	93.6	30.4	30.4
Thermal	7.8	17.6	25.0	85.3	69.2	182.4	70.4	70.4
Total	12.9	28.3	52.8	188.1	99.5	276.0	100.8	100.8
<b>Power/heat ratio</b>	0.67	0.61	1.11	1.20	0.44	0.51	0.43	0.43
<b>Efficiency (LHV %)</b>								
Electric	32%	32%	45%	47%	26%	30%	26%	26%
Thermal	48%	54%	40%	39%	60%	59%	61%	61%
Total	80%	86%	85%	85%	87%	89%	88%	88%
<b>CO2 emissions</b>								
g/MJ (LHV) fuel	57	56	56	56	95	95	107	-
kg/kWhe	0.64	0.62	0.45	0.43	1.29	1.13	1.46	-
<b>Carbon emissions kgC/kWhe</b>	0.17	0.17	0.12	0.12	0.35	0.31	0.40	-
<b>Operating hours</b>	6,500	7,000	7,500	7,500	7,500	7,500	7,500	7,500
<b>Annual energy production (MWH)</b>								
Electricity	33,624	74,830	208,305	770,985	227,627	701,699	227,627	227,627
Heat	50,436	123,470	187,475	639,918	518,990	1,368,313	528,095	528,095
Total	84,060	198,300	395,780	1,410,903	746,617	2,070,012	755,722	755,722
<b>Annual emissions</b>								
Metric tons CO2	21,528	46,354	93,490	333,399	293,028	791,271	332,987	-

### **Conventional heat production with gas-fired boiler**

<b>Efficiency (LHV %)</b>	85%	85%	85%	85%	85%	85%	85%	85%
<b>CO2 emission factors</b>								
kg CO2/MWHth	209	209	209	209	209	209	209	209
<b>Annual emissions</b>								
Metric tons CO2	2,878	7,047	10,700	36,521	29,620	78,092	30,139	30,139

### **Conventional heat production with coal-fired boiler**

<b>Efficiency (LHV %)</b>	85%	85%	85%	85%	85%	85%	85%	85%
<b>CO2 emission factors</b>								
kg CO2/MWHth	401	401	401	401	401	401	401	401
<b>Annual emissions</b>								
Metric tons CO2	5,507	13,481	20,469	69,867	56,664	149,394	57,658	57,658

### **Conventional new gas turbine combined cycle condensing power plant**

<b>Efficiency (LHV %)</b>	54%	54%	54%	54%	54%	54%	54%	54%
<b>Emission factors</b>								
g CO2/MJ fuel	56	56	56	56	56	56	56	56
kg/kWhe	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
kg C/kWhe	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
<b>Annual emissions</b>								
Metric tons CO2	3,412	7,593	21,136	78,229	23,097	71,199	23,097	23,097

### **Using UK Scheme Value for displaced power generation**

kg C/kWhe	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
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### **Marginal displaced conventional power plant capacity**

kg C/kWhe	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
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### **Total emissions comparison (metric tons CO2)**

#### **Assuming conventional power produced with large new gas turbine combined cycle condensing plant**

CHP	5,866	12,631	25,474	90,844	79,844	215,605	90,732	-
Conventional	6,290	14,639	31,836	114,751	79,760	220,593	80,755	80,755
Net reduction	424	2,009	6,361	23,906	(84)	4,988	(9,978)	80,755
% reduction	7%	14%	20%	21%	0%	2%	-12%	100%
Net reduction kg CO2 per MWH heat	8	16	34	37	(0)	4	(19)	153

#### **Assuming UK scheme value for displaced power generation**

CHP	5,866	12,631	25,474	90,844	79,844	215,605	90,732	-
Conventional	6,913	16,026	35,696	129,040	83,979	233,598	84,973	84,973
Net reduction	1,047	3,396	10,222	38,196	4,135	17,993	(5,759)	84,973
% reduction	15%	21%	29%	30%	5%	8%	-7%	100%
Net reduction kg CO2 per MWH heat	21	28	55	60	8	13	(11)	161

#### **Assuming marginal displaced conventional power plant capacity**

CHP	5,866	12,631	25,474	90,844	79,844	215,605	90,732	-
Conventional	9,940	22,761	54,444	198,429	104,466	296,752	105,460	105,460
Net reduction	4,074	10,130	28,970	107,585	24,622	81,146	14,728	105,460
% reduction	41%	45%	53%	54%	24%	27%	14%	100%
Net reduction kg CO2 per MWH heat	81	82	155	168	47	59	28	200

### **Emissions at CHP site compared to production of heat with heat-only boilers (metric tons CO2)**

CHP	5,866	12,631	25,474	90,844	79,844	215,605	90,732	-
Heat-only boilers	2,878	7,047	10,700	36,521	56,664	149,394	57,658	57,658
Net increase	2,988	5,584	14,775	54,323	23,180	66,211	33,074	(57,658)
% increase	104%	79%	138%	149%	41%	44%	57%	-100%

## **Value of carbon dioxide reductions**

### **Value of carbon dioxide reductions at**                                 **\$     5.00 per metric ton CO2**

#### **With displaced power per:**

New gas turbine combined cycle	\$	2,121	\$	10,044	\$	31,807	\$	119,532	\$	(419)	\$	24,939	\$	(49,888)	\$	403,773
UK scheme value	\$	5,237	\$	16,979	\$	51,111	\$	190,979	\$	20,675	\$	89,966	\$	(28,793)	\$	424,867
Marginal displaced capacity	\$	20,368	\$	50,652	\$	144,849	\$	537,925	\$	123,108	\$	405,732	\$	73,639	\$	527,300

#### **Assumed CHP capital cost**

US\$ per kWh	\$	940	\$	960	\$	1,050	\$	900	\$	2,000	\$	1,600	\$	2,000	\$	2,001
Initial cost (million US\$)	\$	4.9	\$	10.3	\$	29.2	\$	92.5	\$	60.7	\$	149.7	\$	60.7	\$	60.7

#### **NPV of CO2 as % of capital (at 5% discount rate)**

##### **With displaced power per:**

New gas turbine combined cycle	0.5%	1.2%	1.3%	1.6%	0.0%	0.2%	-1.0%	8.0%
UK scheme value	1.3%	2.0%	2.1%	2.5%	0.4%	0.7%	-0.6%	8.4%
Marginal displaced capacity	5.0%	5.9%	6.0%	7.0%	2.4%	3.3%	1.5%	10.4%

### **Value of carbon dioxide reductions at**                                 **\$     15.00 per metric ton CO2**

#### **With displaced power per:**

New gas turbine combined cycle	\$	6,362	\$	30,133	\$	95,422	\$	358,595	\$	(1,257)	\$	74,817	\$	(149,663)	\$	1,211,318
UK scheme value	\$	15,710	\$	50,936	\$	153,333	\$	572,937	\$	62,026	\$	269,897	\$	(86,380)	\$	1,274,600
Marginal displaced capacity	\$	61,103	\$	151,957	\$	434,547	\$	1,613,774	\$	369,324	\$	1,217,197	\$	220,918	\$	1,581,899

#### **Assumed CHP capital cost**

US\$ per kWh	\$	940	\$	960	\$	1,050	\$	900	\$	2,000	\$	1,600	\$	2,000	\$	2,001
Initial cost (million US\$)	\$	4.9	\$	10.3	\$	29.2	\$	92.5	\$	60.7	\$	149.7	\$	60.7	\$	60.7

#### **NPV of CO2 as % of capital (at 5% discount rate)**

##### **With displaced power per:**

New gas turbine combined cycle	1.6%	3.5%	3.9%	4.7%	0.0%	0.6%	-3.0%	23.9%
UK scheme value	3.9%	6.0%	6.3%	7.4%	1.2%	2.2%	-1.7%	25.2%
Marginal displaced capacity	15.1%	17.8%	17.9%	20.9%	7.3%	9.8%	4.4%	31.3%

### **Value of carbon dioxide reductions at**                                 **\$     30.00 per metric ton CO2**

#### **With displaced power per:**

New gas turbine combined cycle	\$	12,724	\$	60,265	\$	190,845	\$	717,190	\$	(2,514)	\$	149,634	\$	(299,326)	\$	2,422,635
UK scheme value	\$	31,420	\$	101,872	\$	306,667	\$	1,145,874	\$	124,052	\$	539,794	\$	(172,761)	\$	2,549,201
Marginal displaced capacity	\$	122,205	\$	303,915	\$	869,094	\$	3,227,547	\$	738,649	\$	2,434,394	\$	441,837	\$	3,163,798

#### **Assumed CHP capital cost**

US\$ per kWh	\$	940	\$	960	\$	1,050	\$	900	\$	2,000	\$	1,600	\$	2,000	\$	2,001
Initial cost (million US\$)	\$	4.9	\$	10.3	\$	29.2	\$	92.5	\$	60.7	\$	149.7	\$	60.7	\$	60.7

#### **NPV of CO2 as % of capital (at 5% discount rate)**

##### **With displaced power per:**

New gas turbine combined cycle	3.1%	7.0%	7.9%	9.3%	0.0%	1.2%	-5.9%	47.9%
UK scheme value	7.8%	11.9%	12.6%	14.9%	2.5%	4.3%	-3.4%	50.4%
Marginal displaced capacity	30.2%	35.5%	35.8%	41.9%	14.6%	19.5%	8.7%	62.5%

# Appendix 8: Rewarding Energy Efficiency: The Perspective of Emissions Trading

First presented at Euroheat 30th Congress in Gdynia, June 8, 2001.

Slightly revised and published in Euroheat & Power – Fernwärme International 30(2001):9, 14-21.

## Summary

Hopefully, the flexible mechanisms of the Kyoto protocol will be introduced within some years. As one of the three mechanisms, Emissions Trading will bring an international value for emissions of carbon dioxide to the atmosphere. The district heating community must then estimate the competitive strength of District Heating and Combined Heat and Power (CHP) within an emissions trading system in order to understand and communicate its own position. While waiting for detailed rules and guidelines for an international, an European and various national emissions trading systems, the climate change benefits of district heating and CHP can be estimated by analysing the carbon dioxide emissions for various technical options for heating buildings.

Understanding the climate change benefits of district heating and CHP require knowledge in many dimensions: CHP technologies, technologies for heating alternatives, carbon leanness of various fuels, and the composition of the international electricity market. A demand exists for a simple tool for communication of the benefits of CHP to customers, politicians, the public and policy-makers.

In order to summarise both the technological aspects and the market conditions for district heating and CHP into one dimension, a simple bar diagram has been created for various technical options available for heating buildings. In this bar diagram, all carbon dioxide emissions associated to heating buildings are allocated to the heat produced. The carbon dioxide emission for electricity produced in CHP plants has been set equal to the marginal production on the international electricity market. The bar diagram shows very clearly the carbon dioxide emissions for each individual choice of technical option.

In this article, the bar diagrams are presented for both the current and the future situation with respect to marginal electricity production in the international electricity market. The conclusions for the future are presented from a combination of the current and future situation.

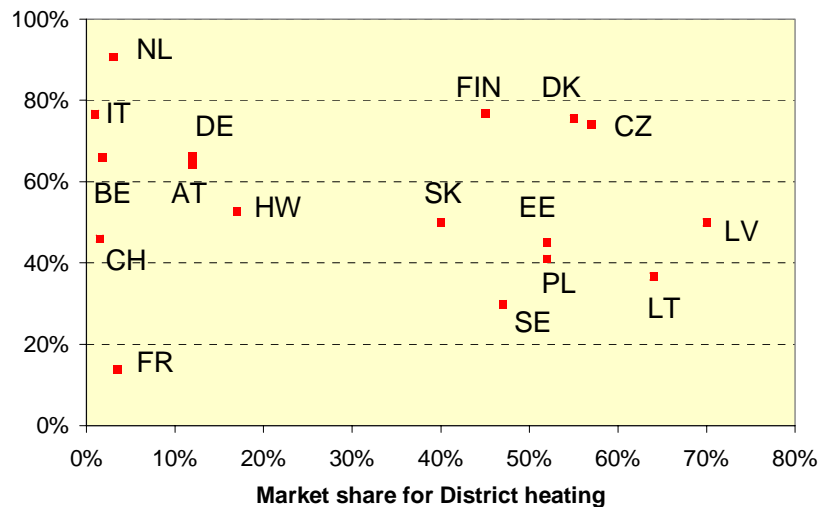
## Introduction

Currently, no general international driving force for carbon lean technologies occurs. Carbon dioxide can normally free of charge be emitted to the atmosphere. Some countries have introduced carbon dioxide taxes into their energy taxation schemes, [3]. But these domestic taxation systems are not complete, since domestic activities exposed for international competition can not be fully taxed without any harmonisation with other countries. Mostly they only consider domestic consumption, as fossil fuels for heating buildings. The industrial and power sectors are normally included with no or reduced taxation in the carbon dioxide taxation systems as they are exposed to international competition. Some countries have also domestic grants or operation support rules for some carbon lean technologies, as for wind power.

Emissions Trading will bring an international value for emissions of carbon dioxide to the atmosphere. In the long term, all sectors will be covered by the same value, although only some sectors and large plants will be covered in the start of the emission trading systems, as proposed in [1].

The district heating community must estimate the competitive strength of district heating and Combined Heat and Power (CHP) within an emissions trading system in order to understand and communicate its own position. While waiting for detailed rules and guidelines for an international, an European [1] and national emissions trading systems [2], the climate change benefits of district heating and CHP can be estimated by analysing the carbon dioxide emissions for various technical options for heating buildings.

### Heat from CHP in district heat generation



**Figure 23.** National combinations of market share for district heating on the domestic heat market and the share of heat from CHP in district heat generation for some European countries in the late 1990's. Source: mainly [4]. Observe that the quality of some combinations can be questioned due to varying statistical background.

The current market share of CHP in conjunction with district heating in Europe, presented in **Figure 23**, can increase, if the district heating community will be able to use the benefits of district heating and CHP within a emissions trading system. The current position of district heating and CHP in Europe is not uniform. No common driving force in an international market economy occurs. The current national positions of district heating and CHP are mostly results from local activities in each country, often connected to a domestic planning process. Therefore, the conditions for district heating and CHP are very domestic, as **Figure 23** reveals. International emissions trading systems can for the first time in the history of district heating and CHP create a common international driving force, harmonising and unifying the conditions for district heating and CHP in various countries.

## The information problem

By tradition, the benefits of district heating and CHP have mainly been explained by technical arguments and approaches communicated by engineers. Often Sankey and power process diagrams have been used. Many explanations have focused on the amounts of fuel saved by using CHP compared to separate generation of heat in local boilers and electricity in condensing power plants, as in the former Soviet Union.

These old explanations were often production-oriented and did not give answers to actual market demands. The Kyoto commitment and subsequent commitments will create a demand for distinct explanations of the benefits of carbon lean technologies as district heating and CHP. These new explanations of district heating and CHP benefits must consider both the short and long term carbon leanness. Short term carbon leanness will explain the ability to contribute to the Kyoto commitment for the period 2008-2012. The long term sustainability and the ability to meet the subsequent commitments will be expressed in the long term carbon leanness.

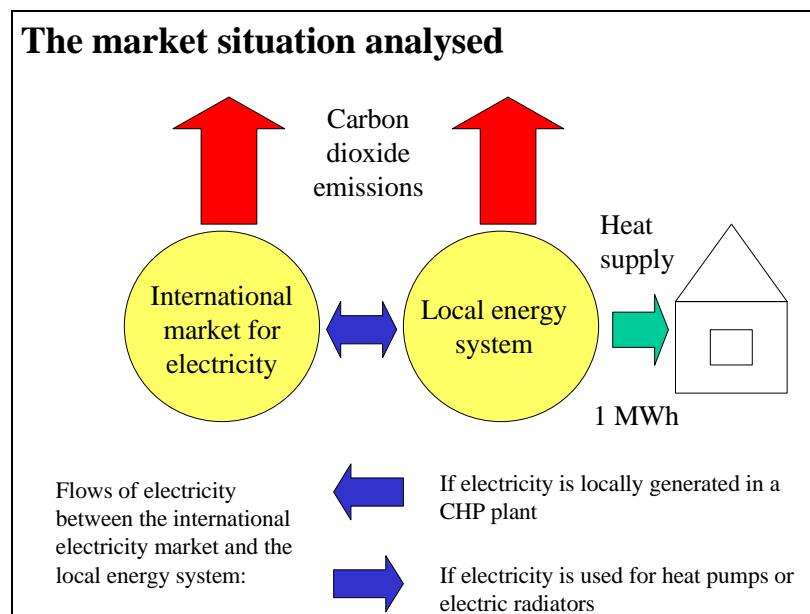
I suggest that the benefits of CHP, with respect to carbon dioxide emissions, are explained from a market situation clearly understandable for the target audience.

## The market situation analysed

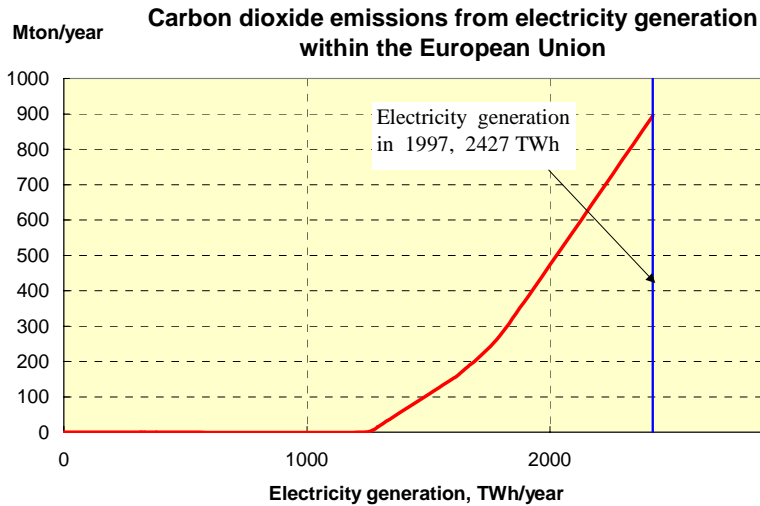
The market situation chosen in this analysis is based on the decision that further 1 MWh (3,6 GJ) heat should be delivered for heating a building. This situation is illustrated in **Figure 24**. The total change of carbon dioxide emissions is estimated from this demand of 1 MWh. The actual change for a flat, building, or a group of buildings can then easily be estimated by multiplying the change of carbon dioxide emissions for 1 MWh by the actual heat demand.

The analysed situation is simplified by not taking account the carbon dioxide emissions from fuel transportation and distribution losses in electricity and district heating networks.

The carbon dioxide emissions in the analysis are split into emissions from the local energy systems ('my own backyard') and emissions from the international electricity market ('the backyard belonging to somebody else'). The local energy systems include all local equipment used for conversion to heat from the energy source used. It may include a CHP plant. The international electricity market include all power plants in the home country and in the neighbouring countries interconnected with cross border transmission lines.



**Figure 24.** The market situation analysed for estimating the net emissions of carbon dioxide from various technical options in the local energy system.



**Figure 25.** The current supply curve for electricity generation with respect to carbon dioxide emissions in the European Union.

Electricity is exchanged between the international electricity market and the local energy system depending on the technical option used. If electricity is used in the local energy systems, electricity is transferred to the local energy system from the international electricity market. The opposite situation occurs, if a CHP plant is used in the local energy system. The CHP plant then replace electricity production somewhere else in the international electricity market.

The baseline for carbon dioxide emissions from the international electricity market is estimated to be the marginal production in the market. This marginal production is the mix of power plants that increase or decrease their production, if the consumption of electricity increase or decrease. With an international emissions trading system, the marginal production should be the power plants with the highest carbon dioxide emissions giving the highest running costs. Hence, the carbon dioxide emission for electricity produced in CHP plants has been set equal to the marginal production in the international electricity market.

In the current market for electricity in the European Union, the short term marginal production, with respect to amounts of electricity, is considered to be *coal condensing plants*. Peak generation of electricity is not considered in this short term marginal production, since peak plants only satisfy daily and annual peak capacity needs.

The supply curve for electricity generation for the European market with respect to carbon dioxide emissions is presented in **Figure 25**. The average carbon dioxide emission from the European electricity market is about 370 kg per MWh produced. However, at lower production levels, no carbon dioxide is emitted since the electricity is produced in hydro, nuclear, biomass, and wind power plants. At higher production levels, the slope of the curve increase since more carbon dioxide is emitted from power plants. The highest slope (about 1000 kg/MWh) originating from coal condensing plants occurs in the upper end of the curve just before reaching the current production level (2400-2500 TWh) is reached.

For the long term, *gas combined cycle condensing plants* should be considered as marginal production in the international electricity market. Nobody can tell today when this shift of marginal production will occur. Probably, it will be a transition starting within 10-30 years and ending within 20-40 years. More than 100000 MW are required to replace existing coal condensing plants. Investments of more than 100 billion Euro will be required in order to create a transition from coal to gas combined cycle condensing plants as marginal production in Europe.



## Input for the analysis

The following 11 technical options for heating buildings are examined in the analysis:

<u>5 CHP options</u>	<u>6 Heat only options</u>
Gasified biomass, Combined Cycle CHP	Industrial waste heat
Natural Gas, Combined Cycle CHP	Biomass, Heat only boiler
Biomass, Steam cycle CHP	Natural Gas, Heat only boiler
Oil, Steam cycle CHP	Oil, Heat only boiler
Coal, Steam cycle CHP	Heat pump
	Electric Heating

All assumptions used for the analysis are presented in **Table 3**. Biomass is considered to have no net contribution to an increasing content of carbon dioxide in the atmosphere, since use of biomass is a part of a natural orbit of carbon. No carbon dioxide is allocated to industrial waste heat, since all industrial emissions are allocated to the primary use, which is the industrial products.

All technical options reviewed can be considered as commercially available, except for the combined cycle CHP using gasified biomass. This option can only be seen as an interesting long term option.

**Table 3.** Assumptions made for the analysis performed.

Fuel	Specific carbon dioxide emissions, g/MJ fuel	CHP-technologies		Heat technologies Conversion efficiency	Power technologies Conversion efficiency
		Conversion efficiency	Power-to-heat-ratio Steam cycle    Combined cycle		
Natural gas	56	85%	100%	90%	57%
Biomass	0	85%	50%    100%	90%	
Oil	76	90%	60%		
Coal	92	88%	60%		33%

The heat factor for a local heat pump is assumed to be 3.

## The current situation

The result of the analysis for the current situation is presented in **Table 4** and **Figure 26**.

The highest net emissions are obtained from options that use electricity (electric heating and heat pump), while negative net emissions are obtained for various CHP options. The bar diagram in **Figure 26** shows how well various combinations of fuels and CHP technologies plants can reduce the existing carbon dioxide emissions compared to other technical options for heating a new or existing building.

The bar diagram reveals the well-known CHP paradox, that increased heat sales from a CHP plant will decrease the current global emissions of carbon dioxide. In this context, CHP together with district heating works as a lever with respect to lower carbon dioxide emissions.

The bar diagram in **Figure 26** can also be used to estimate the overall change in carbon dioxide emissions when changing option for heating a building. Two short examples will illustrate the competitive strength for a switch:

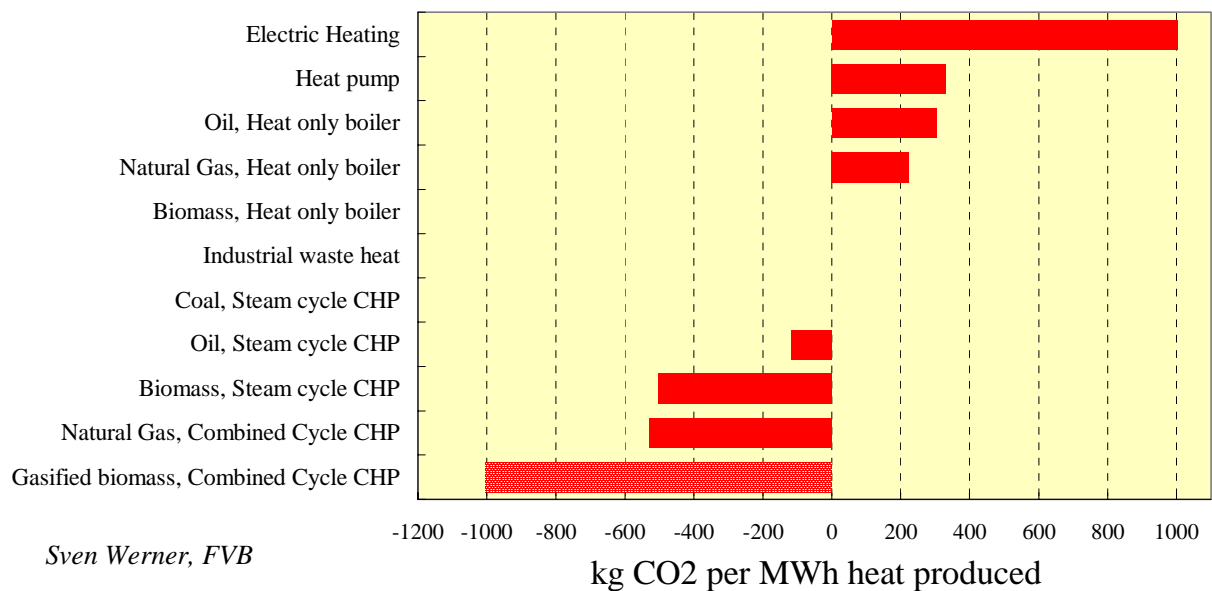
1. A building using 200 MWh heat per year for heating, will switch from a local gas boiler to a district heating system using a gas combined cycle CHP as a heat source. The total increase in local emissions will be  $200 \cdot (474 - 224) = 50000$  kg/year, but the international emissions will decrease with  $1004 \cdot 200 = 200800$  kg/year, giving a total decrease of 150000 kg/year. With an international price of emissions traded of 10 EUR per ton, the switch will be supported by a driving force of 1500 EUR per year. At a heat price of 40 EUR/MWh, this driving force corresponds to almost 20% of the heat price.
  2. The corresponding switch from electric heating to the same district heating option used above will give a driving force of 3060 EUR per year, corresponding to almost 40% of the heat price.
- Remark: The price of carbon dioxide traded used above is half of what is considered as a reference level in [5] and [6].

**Table 4.** Analysis performed for 1 MWh of heat further delivered in the CURRENT situation when coal condensing plants are marginal production in the international electricity market.

Technical option	Change in local emissions, kg/MWh	Change in international emissions, kg/MWh	Net emissions, kg/MWh
Gasified biomass, Combined Cycle CHP	0	-1004	-1004
Natural Gas, Combined Cycle CHP	474	-1004	-529
Biomass, Steam cycle CHP	0	-502	-502
Oil, Steam cycle CHP	486	-602	-116
Coal, Steam cycle CHP	602	-602	0
Industrial waste heat	0	0	0
Biomass, Heat only boiler	0	0	0
Natural Gas, Heat only boiler	224	0	224
Oil, Heat only boiler	304	0	304
Heat pump	0	335	335
Electric Heating	0	1004	1004

### HEATING BUILDINGS: Net emissions of carbon dioxide for various fuels and technical options.

THE CURRENT SITUATION: coal condensing plants are marginal production in the international electricity market



**Figure 26.** The simple bar diagram for the CURRENT situation.

## The future situation

The result of the analysis for the future situation is presented in **Table 5** and **Figure 27**.

The major changes compared to the current situation are lower net emissions for options using electricity, while CHP options using fossil fuels will lose competitive strength. Options lacking a connection to the international electricity market will have the same net emissions as in the current situation. Only CHP options using biomass will have negative net emissions. All CHP options using fossil fuels will have positive net emissions of carbon dioxide.

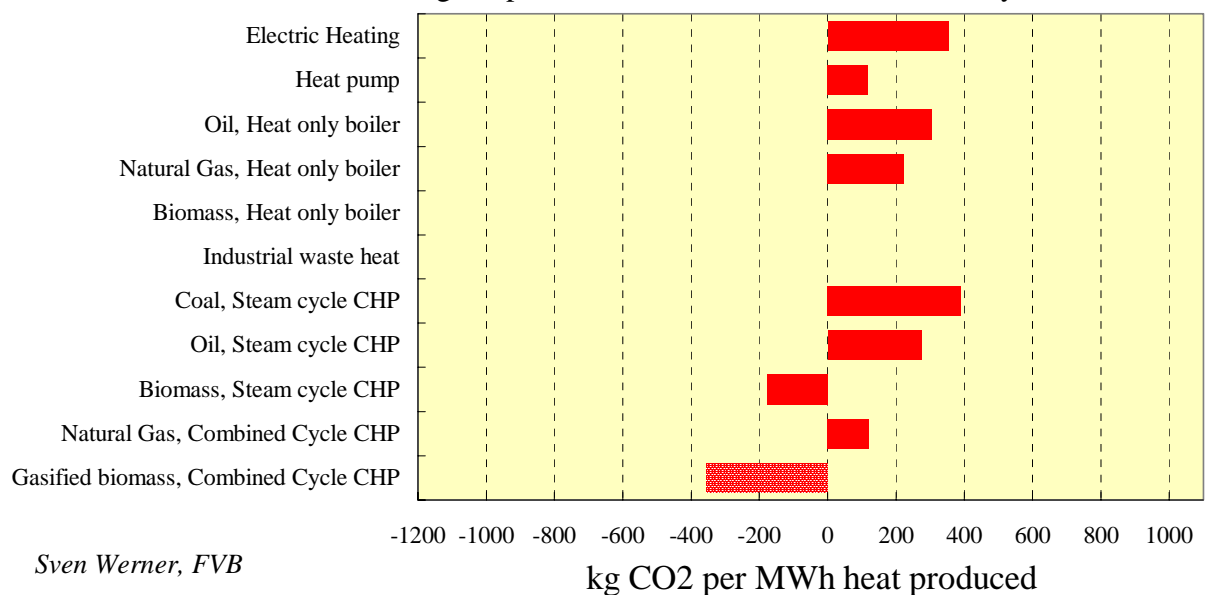
Gas combined cycle CHP and heat pumps will have the same net emissions, which is correct with respect to the second law of thermodynamics. This means that gas combined cycle CHP must be considered as a tool for carbon dioxide reduction as long as a heat pump is considered as a tool.

**Table 5.** Analysis performed for 1 MWh of heat further delivered in the *FUTURE* situation when gas combined cycle condensing plants are marginal production in the international electricity market.

Technical option	Change in local emissions, kg/MWh	Change in international emissions, kg/MWh	Net emissions, kg/MWh
Gasified biomass, Combined Cycle CHP	0	-354	-354
Natural Gas, Combined Cycle CHP	474	-354	121
Biomass, Steam cycle CHP	0	-177	-177
Oil, Steam cycle CHP	486	-212	274
Coal, Steam cycle CHP	602	-212	390
Industrial waste heat	0	0	0
Biomass, Heat only boiler	0	0	0
Natural Gas, Heat only boiler	224	0	224
Oil, Heat only boiler	304	0	304
Heat pump	0	118	118
Electric Heating	0	354	354

## HEATING BUILDINGS: Net emissions of carbon dioxide for various fuels and technical options.

THE FUTURE SITUATION: **gas combined cycle condensing plants** are marginal production in the international electricity market



**Figure 27.** The simple bar diagram for the *FUTURE* situation.

## Combination of the current and the future situation

In order to identify the combination of both short and long term abilities to reduce the carbon dioxide emissions, information from both analyses have been combined in **Figure 28**.

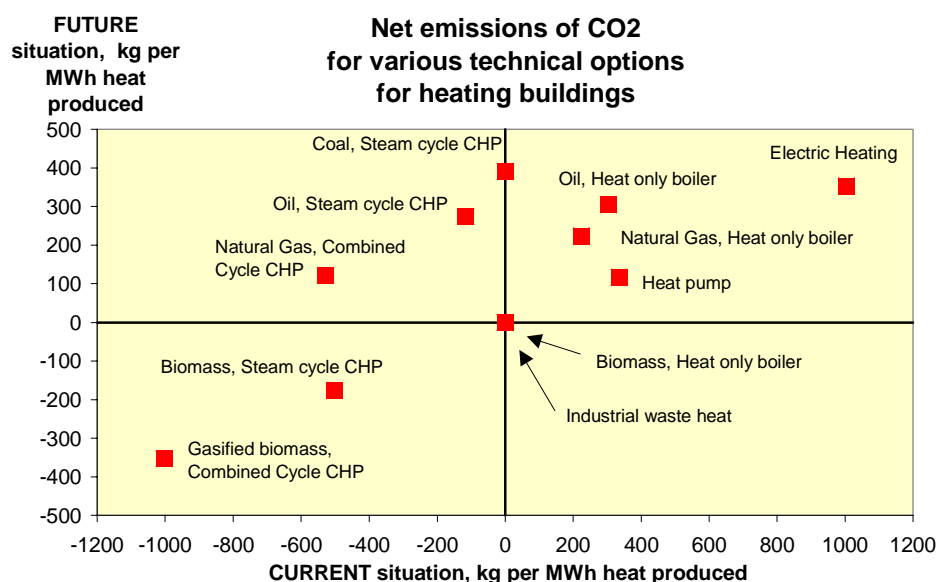
In the upper right part of the diagram, all options that always will contribute to higher carbon dioxide emissions are gathered. These are electric heating and heat pumps, which both use electricity as local energy source, and using oil or natural gas in a local boiler. Options that always reduce carbon dioxide emission can be found in the lower left part of the diagram. These are CHP options using non-fossil fuels.

Options that first gain competitive strength in the short term and then loose competitive strength in the long term are located to the upper left part. These are all CHP options using fossil fuels. Especially natural gas combined cycle CHP is very efficient to reduce emissions in the short term, but will in the long run give a net contribution to increasing content of carbon dioxide in atmosphere.

The immediate conclusion from this combined analysis is that district heating and CHP can contribute significantly to reductions of the carbon dioxide emissions in the short term perspective, 10-20 years. The foundation for this conclusion is that the international electricity market will have high marginal emissions of carbon dioxide. Therefore, emissions trading will provide an added competitive strength to district heating and CHP in the short term.

In the long term perspective, 20-40 years, the marginal emissions from the international electricity market will probably be lower than today. Hence, the competitive strength for district heating and conventional CHP using fossil fuels will be weaker. Also the driving force from a emissions trading system will be weaker for the district heating community.

A long term strategy for the European district heating community could be to use the increased competitive strength in the short term supported by a emissions trading system to increase the market shares for district heating. This would be to cut use of options in the upper right part of **Figure 28** and increase use of options in the upper left part. The next long term step would be to replace the existing CHP plants to plants that use non-fossil fuels or carbon lean fuels. This would be to move from the upper left part to the lower left part in **Figure 28**.



**Figure 28.** Combination of the current and the future situation for various technical options for heating buildings.

## **Final conclusions**

In the short term, the combination of district heating and CHP is a carbon lean technology that will gain strong initial competitive strength from emissions trading systems. Hence, the contribution from district heating and CHP can be significant for fulfilling the Kyoto commitment for 2008-2012. This situation will occur, since the marginal production in the current international electricity market in Europe has high carbon dioxide emissions, due to use of coal as fuel and the low efficiencies used.

The overall conclusion will be that district heating and CHP can be justified when other competing alternatives on the energy market has high carbon dioxide emissions and low efficiencies. When the marginal production in the international electricity market will reduce its emissions and reach higher efficiencies, conventional district heating using CHP plants with fossil fuels will loose competitive strength.

The final conclusion from this article will be that emissions trading systems can offer an unique initial opportunity when they are introduced, since the European district heating community has an initial advantage of low carbon dioxide emissions. This advantage with respect to carbon dioxide emissions will be weaker in the long term perspective. However, this is not a unique situation for district heating and CHP. This situation is valid for all carbon lean technologies, since the future competition will not come from carbon rich technologies, but from other carbon lean technologies.

## **Acknowledgement**

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## **References**

- [1] Commission of The European Communities, Green Paper on Greenhouse Gas Emissions Trading within the European Union, COM (2000) 87 final.
- [2] Hasselknippe, H. & Høiby, G., Meeting the Kyoto Protocol Commitments, Summary of domestic emissions trading schemes, January 2001. Available at [www.nho.no](http://www.nho.no)
- [3] Speck, S., Ekins, P., Recent Trends in the Application of Economic Instruments in EU Member States plus Norway and Switzerland and an Overview of Economic Instruments in Central and Eastern Europe, Update of Database of Environmental Taxes and Charges. July 2000, Forum for the Future, London, available at [www.europa.eu.int/comm/environment/enveco/env\\_database/database.htm](http://www.europa.eu.int/comm/environment/enveco/env_database/database.htm)
- [4] Euroheat & Power, District Heat in Europe, 1999 Survey, Brussels 1999.
- [5] Commission of The European Communities, The European Climate Change Programme, Long report, June 2001, available at [www.europa.eu.int/comm/environment/climat/eccp.htm](http://www.europa.eu.int/comm/environment/climat/eccp.htm)
- [6] Blok, K., de Jager, D., Hendriks, C., Economic Evaluation of Sectoral Emission Reduction Objectives for Climate Change, Summary for Policy Makers, March 2001, available at [www.europa.eu.int/comm/environment/enveco/climate\\_change/sectoral\\_objectives.htm](http://www.europa.eu.int/comm/environment/enveco/climate_change/sectoral_objectives.htm)