District Heating and Cooling: Environmental Technology for the 21st 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[1] 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.

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

Myths and Misconceptions

District heating is not competitive with distributed systems

Linking buildings with DHC opens up technology options

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.

District heating systems are yesterday's technology

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.

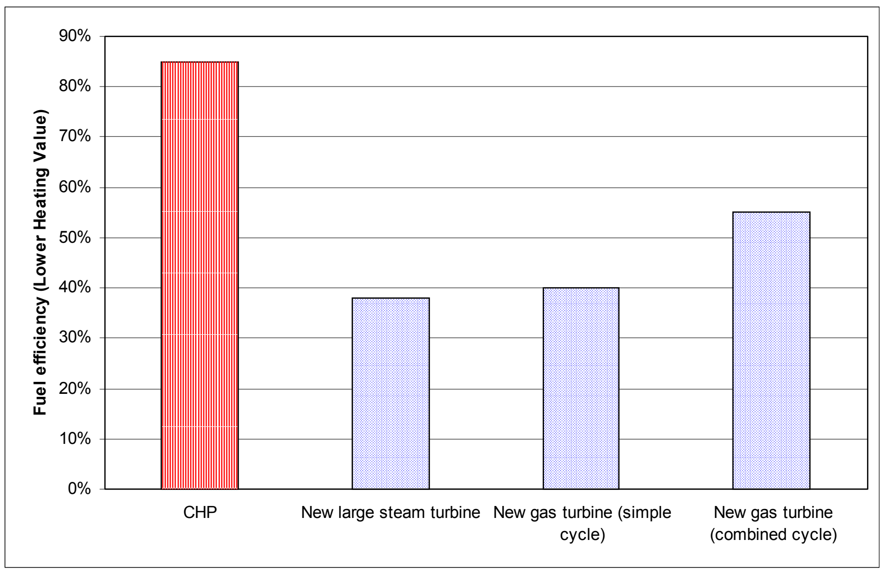
Impact on Key Policy Issues

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

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.

CHP enables growing power demands to be met efficiently



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_2 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)[2] 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.

[2] 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.

Biomass transition

DHC provides a flexible infra-structure 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.[3, 4] 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 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

[3] New and Renewable Energy: Prospects for the 21st Century DTI Consultative Paper.
[4] Energy for the Future:Renewable Sources of Energy. White paper for a Community Strategy and Action Plan COM(97) 599 26/11/97

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 increasing 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.

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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.

Ease barriers to connection of CHP to power and gas grids

However, until that transition is successful, a number of issues remain problematic in many markets, including:

- 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.

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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 38th meeting in Copenhagen on 16 May 2002.