IEA - District Heating and Cooling Project

District Heating and Cooling in Future Buildings

(DH&C-FB)

by

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PREFACE AND ACKNOWLEDGEMENTS

The International Energy Agency (IEA) was established in 1974 within the framework of the OECD to implement an International Energy Program. A basic aim of the IEA is to strengthen the co-operation between the member countries in the energy field. One element of these co-operative activities is to undertake energy research, development and demonstration (RD&D).

District Heating is, by the IEA, seen as a means by which countries may reduce their dependence on oil and improve their energy efficiency. It involves increased use of indigenous or abundant fuels, the utilisation of waste energy and combined heat and power production.

The IEA "Program of Research, Development and Demonstration on District Heating" was established at the end of 1983. Under Annex I, ten countries participated in the program: Belgium, Canada, Denmark, Federal Republic of Germany, Finland, Italy, The Netherlands, Norway, Sweden and USA.

The National Energy Administration, Sweden was Operating Agent for the program under Annex I, in which the following technical areas were assessed:

- Development of heat meters
- Cost efficient distribution and connection systems for areas of low heating density
- Small size coal-fired hot water boiler
- Medium size combined heat and power plants
- Low temperature applications in district heating systems

The results of these topics have been presented in printed reports published by the National Energy Administration, Sweden.

In 1987 it was decided by nine of the original ten participating countries (ex. Belgium) to continue the implementation of co-operative projects under an Annex II.

The Netherlands Agency for Energy and the Environment (NOVEM), was Operating Agent for Annex II, in which the following technical areas were assessed:

- Heat meters
- Consumer installations
- Piping
- Advanced fluids
- Advanced heat production technology
- Information exchange

In 1990 the co-operating countries decided to continue the implementation of new co-operative projects under a new Annex III. During this annex United Kingdom joined the project. NOVEM was Operating Agent also for Annex III, in which the following areas have been assessed:

- District Heating and the Environment
- Supervision of District Heating Networks
- Advanced Fluids
- Piping
- District Energy Promotion Manual
- Consumer Heating System Simulation

In 1993 the co-operating countries (ex. Italy) decided to continue the implementation of new co-operative projects under a new Annex IV. The name of the main co-operating project was now changed to "IEA - District Heating and Cooling Project", which emphasise the increasing awareness of District Cooling as an energy efficient technology.

During this annex The Republic of Korea joined the project. NOVEM has been Operating Agent also for Annex IV, in which the following technical areas have been assessed:

- Combined Heat and Power/Cooling Guidelines
- Advanced Transmission Fluids
- Piping Technology
- Network Supervision
- Efficient Substations and Installations (ESI)
- Manual on DH-piping, Design and Construction
- Development of long term Co-operation with East-European Countries

The results from Annex II, III and IV have been presented in printed reports published by NOVEM.

In 1996 the co-operating countries decided to continue the implementation of new co-operative projects under a new Annex V in which the following technical areas have been assessed:

- Cost effective DH&C networks
- Fatigue analysis of DH networks
- Optimization of low temperature DH-systems
- **District Heating and Cooling in Future Buildings**
- Balancing the production and demand in CHP
- Plastic pipe DH-systems - Handbook

The report at hand describes the project called **"**District Heating and Cooling in Future Buildings**"** (DH&C-FB).

The work on the project DH&C-FB- has been monitored by the "IEA-Experts Group on DH&C-FB" (EG-DH&C-FB), with Associate Professor Rolf Ulseth from The Norwegian University of Science and Technology (NTNU) as project leader.

The members of "EG- DH&C-FB" have been:

- Mirja Tiitinen (Finland)
- Zoltán Korényi (Germany)
- Joo Tae Ahn (Korea)
- Gert Boxem (The Netherlands)
- Monica Havskjold/Heidi Juhler (Norway)
- Gunnar Nilsson (Sweden)
- Robin Wiltshire (United Kingdom)

The project leader wants to thank everybody who has contributed and made it possible to carry through this work - especially every individual of the EG for making a good effort and showing a positive will to co-operate. A special thank to, Jacob Stang, Tor I Hoel, Peter Noeres, P. Klose, D. Hölder, W. Althaus, Markku Ahonen and Ki-Dong Koo for their supportive contribution to the joint work and in the effort to make the report.

Thanks should also be given to the "Executive Committee" who gave priority to do work on the DH&C-FB-project.

On behalf of SINTEF Energy Research, I will also take this opportunity to thank "The Research Council of Norway" for the financial support that made possible our participation in "The IEA-District Heating and Cooling Project".

The technical development in all countries, on this and adjacent fields, depend on research co-operation on such international projects. And besides – the benefit from the network of professional colleagues you learn to know by the co-operation is invaluable.

SINTEF Energy Research, April 1999

Rolf Ulseth
Project leader

District Heating and Cooling in Future Buildings

Summary

By Rolf Ulseth

For the future development of District Heating (DH) and District Cooling (DC) the development of the heating and cooling consumption is assumed to be an important factor for the economic feasibility of these technologies.

On this background the IEA-District Heating and Cooling Project has given priority to a research project called District Heating and Cooling in Future Buildings. The main goal of the project has been to get a picture of the expected development of the heating and the cooling consumption in the future building stock compared to the building stock of today.

A simulation tool has been used to calculate the heating and cooling loads and the energy consumption in a "typical" office building and a "typical" residential building from 1990, and comparisons are made with the same expected "typical" buildings in 2005+.

The simulations are performed for a typical climatic situation in the respective four countries; Norway (N), Finland (F), Germany (G) and Korea (K).

The input data for the building structure are based on the national building codes in the respective countries. The input data for the local climate are based on a standardised "reference year". A slide in the room temperature from 21°C to 25°C is accepted before cooling is introduced.

The results of the simulations are presented by so-called duration curves and figures with comparative results for the heating and cooling loads and the heating and cooling consumption. Equivalent time of maximum load is also calculated, and the effect of an allowed sliding in the room temperatures before cooling is introduced is shown.

Based on the results from the simulations, the project has also focused on some subsidiary goals:

- Reduction of electric energy consumption and peak power by DC compared to conventional local cooling plants
- Primary energy savings by DH compared to local heating systems
- Environmental benefits from DH&DC compared to local heating and cooling plants

Some examples of the results are shown in figure 1-8.
The simulated load figures are mean hourly values.

The project has been performed at SINTEF Energy Research (N) with project support from VTT Building Technology (F), Fraunhofer UMSICHT (G) and Korea District Heating Corporation (K).

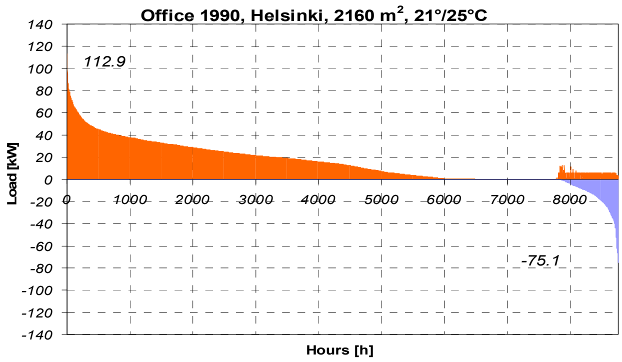

Figure 1 Duration curves for heating and cooling for a "1990 office building" in Helsinki.

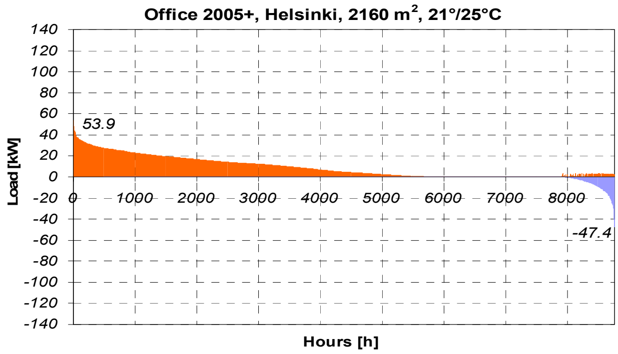

Figure 2 Duration curves for heating and cooling for a "2005+ office building" in Helsinki.

From figure 1 and 2, we can see that the heating and the cooling loads are expected to decrease by 2005+ compared to 1990. The main reasons for this is in this case a better insulated building envelope and a reduced amount of ventilation air.

Figure 3 and 4 show the specific values for the total, yearly heating and cooling energy consumption for the office buildings in the respective four countries.

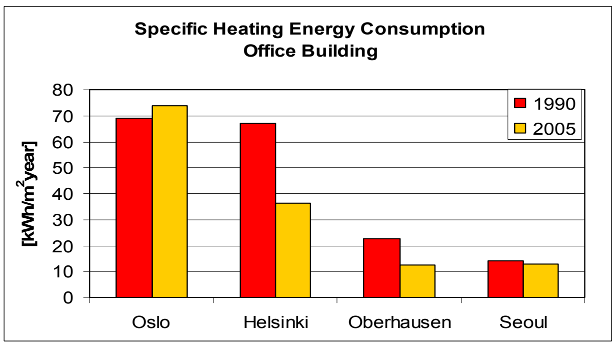

Figure 3 Specific values for the total, yearly heating energy consumption. Simulated values.

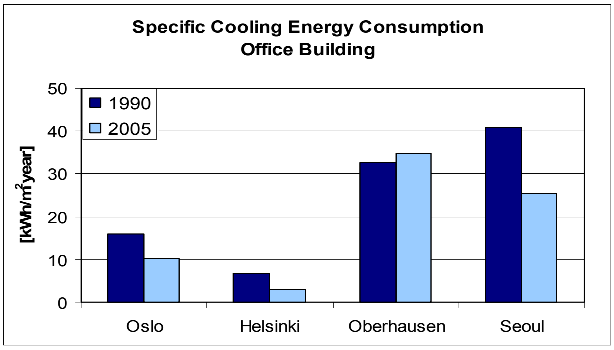

Figure 4 Specific values for the total, yearly cooling energy consumption. Simulated values.

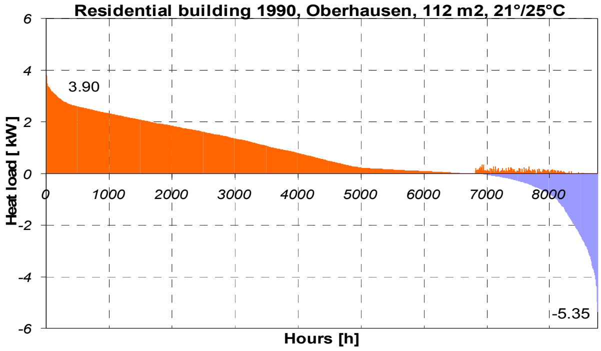

Figure 5 Duration curves for heating and cooling for a "1990 residential building" in Oberhausen

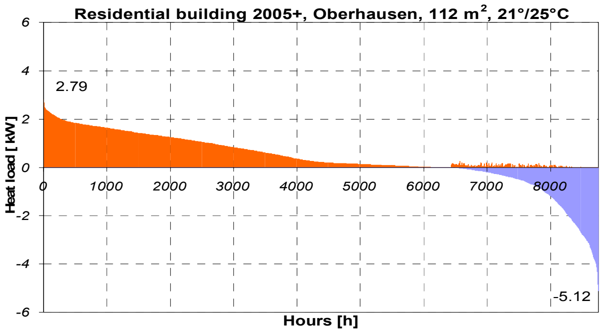

Figure 6 Duration curves for heating and cooling for a "2005+ residential building" in Oberhausen

The reasons for the variations in the simulation results from case to case are of cause a combination of a lot of different factors.

The slight increase in the total heating consumption for the 2005+ building in Oslo is caused by a new building code, which demands a certain amount of ventilation even at night due to the contaminants from the building materials. The reduced cooling load for the Oslo building is mainly cased by reduced ventilation rates.

The reduction of the total heating consumption for the 2005+ building in Helsinki is mainly caused by an expected better insulation of the building envelope, especially for the windows. The ventilation rates are also reduced.

The low values of the total heating consumption for the office building in Oberhausen is caused by the fact that no mechanical ventilation are anticipated. For the 2005+ building the building envelope is better insulated. The high values for the cooling consumption in Oberhausen are mainly due to the comparatively warm summer climate.

The values of the total heating consumption for the office building in Seoul are partly caused by the climatic conditions. The fact that a night setback of the room temperature is anticipated for the Seoul case will also reduce the heating consumption. The more or less steady value for the heat consumption from 1990 to 2005+ is caused by the fact that the effect of an anticipated better insulation is counteracted by in increased ventilation rate.

Figure 5 and 6 show the duration curves for the residential building in Oberhausen. In both cases just natural ventilation is anticipated. The main reasons for the decrease of the heat consumption for the future building are better insulated building envelope and an anticipated lower infiltration rate.

Figure 7 and 8 show the specific values for the total, yearly heating and cooling energy consumption for the residential buildings in the respective countries.

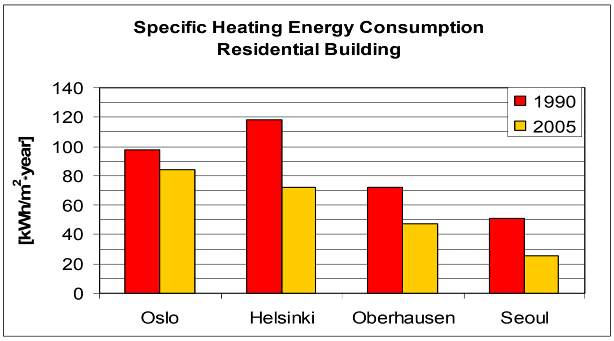

Figure 7 Specific values for the total, yearly heating energy consumption. Simulated values.

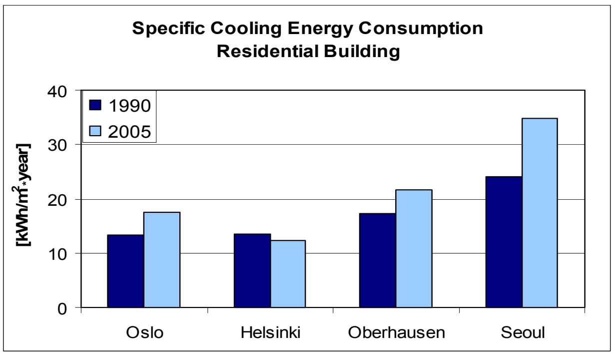

Figure 8 Specific values for the total, yearly cooling energy consumption. Simulated values.

It is commonly known that the peek power on the electricity grid in modern cities in warmer climate normally occurs in the summer time when small, electric driven, cooling equipment and smaller local cooling plants are running for air conditioning of residential and commercial buildings.

One of the reasons for this is that smaller cooling equipment has a low ratio between the cooling output and the electricity input to the cooling compressor as shown in figure 9.

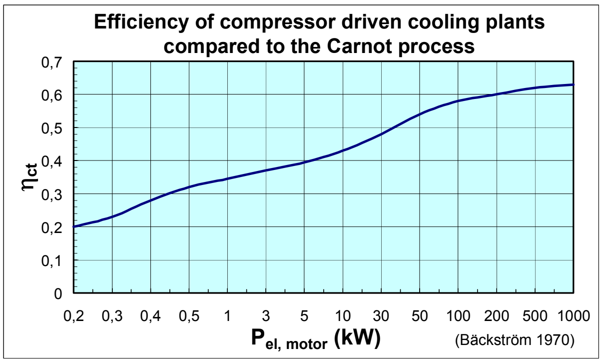

Figure 9 Efficiency curve for an average cooling plant as function of the size of the motor of the electric compressor compared to a Carnot process

From the results from the simulation a calculation of the reduction of electric energy consumption and peak power by DC compared to conventional local cooling plants could be done.

The calculations, which were done for the office buildings, did show that the yearly electric energy consumption and the peek power could be reduced in the range of 30 % or higher by DC compared to conventional local cooling plants.

The calculations for the residential buildings did show that the yearly electric energy consumption and peek power could be reduced in the range of 45 % or higher by DC compared to local, conventional wall or window mounted cooling equipment in the flat.

One of the subsidiary goals of the work was also to look upon the possibility for primary energy savings by DH compared to local heating systems in order to give the different system a “quality ranking”.

This is a rather complicated task, since DH may be produced in many different ways. Reduced use of fossil fuels was focused in the ranking judgements.

The situation on the heating market is also very different from one country to another. Figure 10 shows the heating systems for space heat in some selected countries. The missing amount in each country is provided by other sources.

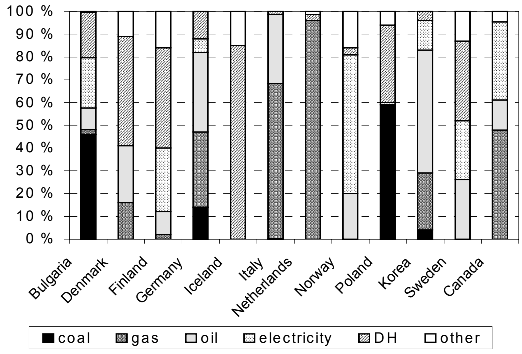

Figure 10 Type of residential heating in some selected countries /Unichal 1995/

As a conclusion a principal ranking of the different processes for the heat supply is given as follows (in order of an increasing use of fossil primary energy):

1. Use of industrial waste heat and waste incineration, CHP and DH driven with biomass, heat pump driven by biomass.
2. Electrical heat pumps, electrical heating systems, electricity from **regenerative** energy sources, provided that electricity cannot be used sensibly at other locations to substitute fossil energy sources [1]
3. CHP + DH by fossil fuels
4. Heat pump processes (local or in combination with DH)
5. Condensing boiler
6. Gas boiler, oil boiler
7. Electrical heating (electricity from fossil energy sources)

By the ranking of no 4, it is presupposed that the Coefficient Of Performance (COP) of the heat pump is sufficiently high to degrade the next on the list.

Depending on the composition of the generated electricity (ratio between renewable and fossil electricity generation) a detailed assessment with exact prevailing circumstances is necessary. An energetic assessment of heat supply systems is only possible and correct if the electricity supply is taken into account too.

Since the ranking the processes is based on reduced use of fossil fuels, this ranking will also gives a strategy for achieving environmental benefits from DH&C. Calculated examples with Finland as reference country shows that further development of CHP has the greatest potential for reduction of the emission of CO_2, SO_2 and NO_x.

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1 The emphasis lays on the phrase “**electricity from regenerative energy sources**”. Only in this case the use of electricity is desirable. In reality we should expect better possibilities to use electricity for heating applications (for example by electricity export to other countries).

District Heating and Cooling in Future Buildings

INTRODUCTION TO THE JOINT REPORT

The main objective of the present work has been to sort out the new conditions for the future expansion of DH and DC that will be caused by the changes that can be foreseen in the future building stock. The anticipated development of heating and cooling will be in focus.

It was decided from the start that the DH&C-FB-project should be performed as a joint project between SINTEF Energy Research, Fraunhofer UMSICHT, VTT Building Technology and Korea District Heating Corporation.

On this background, and for technical reasons, it was found appropriate to make the joint report in the following four parts:

Part I:

District Heating and Cooling in Future Buildings

Part II:

Reduction of Electric Energy Consumption and Peek Power by DC Compared to Conventional Local Cooling Plants

Part III:

Primary Energy Savings by District Heating Compared to Local Heating Systems

Part IV:

Environmental Benefits by DH&DC Compared to Local Heating and Cooling Plants