District Heating and Cooling in Future Buildings (T5)

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).
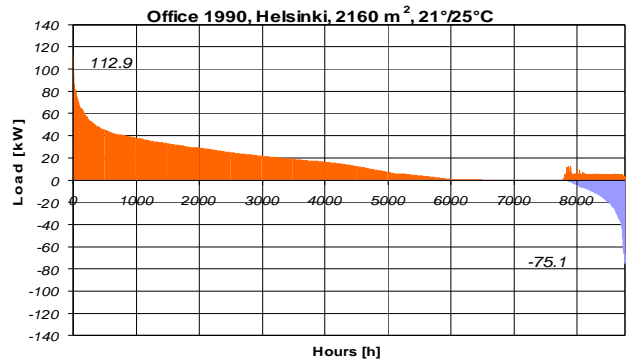

Figure 1   **Duration curves for heating and cooling for a "1990 office building" in Helsinki.**
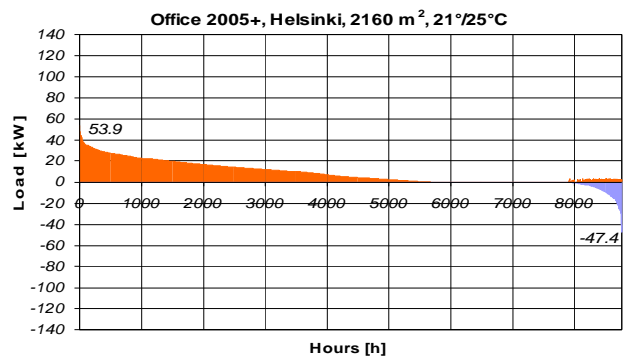

Figure 2   **Duration curves for heating and cooling for a "2005+ office building" in Helsinki.**

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.
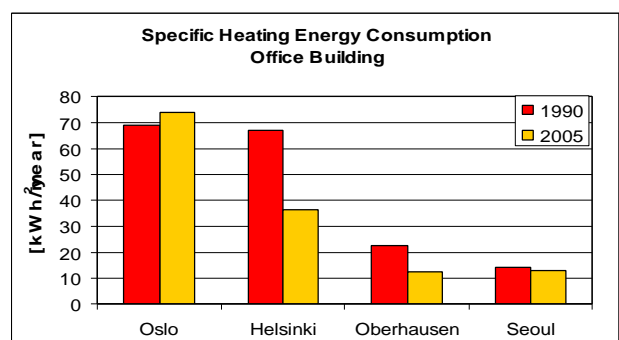

Figure 3   **Specific values for the total, yearly heating energy consumption. Simulated values.**
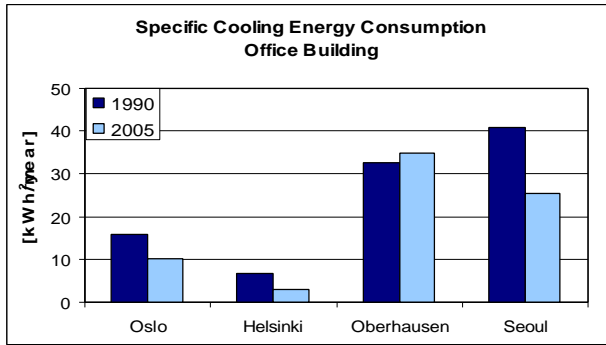
Figure 4 **Specific values for the total, yearly cooling energy consumption. Simulated values.**

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.
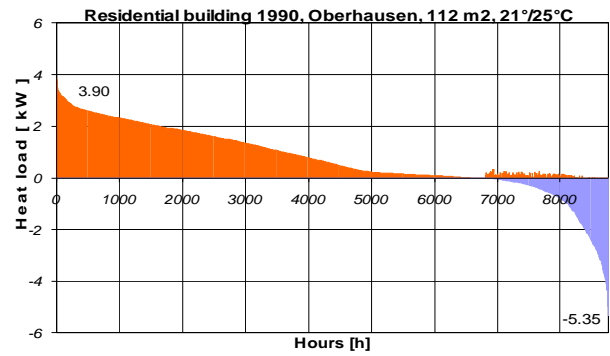

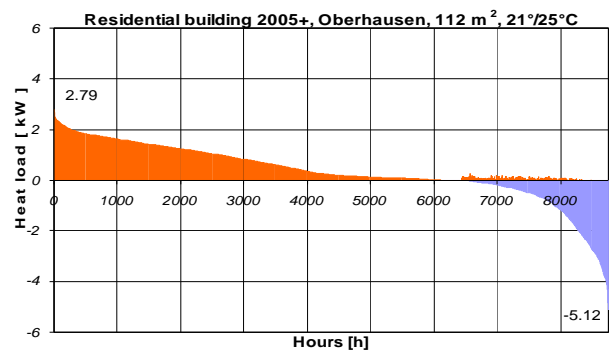**Figure 5** **Duration curves for heating and cooling for a "1990 residential building" in Oberhausen**

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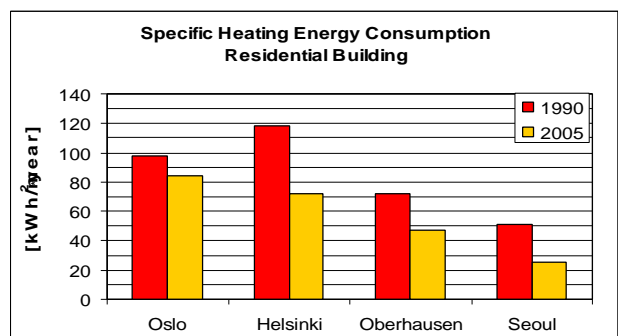

Figure 7 **Specific values for the total, yearly heating energy consumption. Simulated values.**
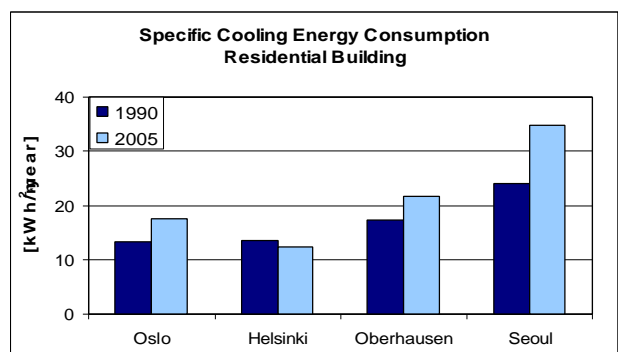

Figure 8 **Specific values for the total, yearly cooling energy consumption. Simulated values.**

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.
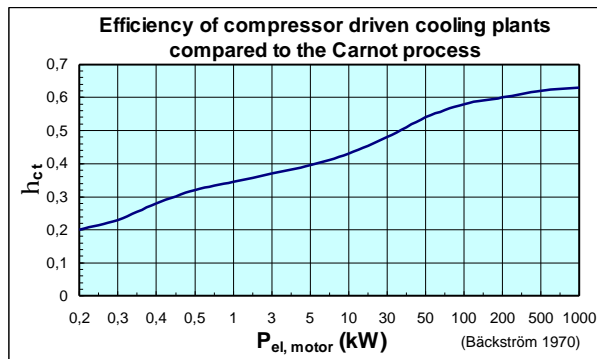

Figure 9   Efficiency curve for an average cooling plant as function of the size of the motor of the electric compressor compared to a Carnot process

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.
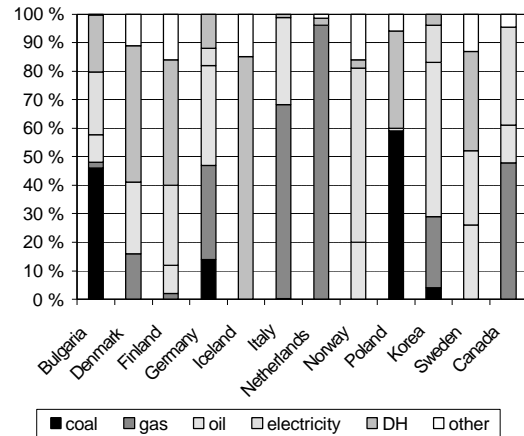

Figure 10   Type of residential heating in some selected countries /Unichal 1995/

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).