Part I:

District Heating and Cooling in Future Buildings

By

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1. District Heating and Cooling in Future Buildings (Part I)

1.1 Background

Efficient use of energy and energy saving in buildings are expected to be very focused areas in the future due to resource policy, environmental reasons, and the fact that the cost of energy is expected to increase relatively more than most other products. One of the consequences of this evolution is a constant development of better insulation of buildings.

This evolution has already - to some extent - changed the problem of controlling indoor temperatures in buildings from being mainly a heating problem to be an integrated heating and cooling problem. This evolution may have some effects on the competitiveness of District Heating and District Cooling in the future.

1.2 Objective of the IEA-project

The main objective of the project is to sort out the new conditions for the future expansion of District Heating (DH) and District Cooling (DC) that will be caused by the changes we can foresee in the future building stock. Expected development of the heating and the cooling loads and energy consumption patterns are in focus.

1.3 The project

The project is organised as a co-operation project between SINTEF Energy Research (N), VTT Building Technology (F), Fraunhofer UMSICHT (G) and Korea District Heating Corporation (K), with the project leadership at SINTEF, and with project support concerning input values for simulations (See page 8) from the other partners. The project is monitored by an "Experts Group" consisting of appointed members from seven of the member countries of Annex V of the IEA-District Heating and Cooling Project.

A basic goal of the project is to map the heating and cooling loads and the energy consumption in a "typical" office building and a "typical" residential building from 1990, and make comparisons with the same expected "typical" buildings in 2005+. A simulation tool is used for the study. The simulations for the actual countries are done for the same defined "standard" building configuration.

The defined "standard" office building and the defined "standard" residential building has been discussed and agreed on in the "Experts Group".

The office building has four storeys, with the floor area of 18m • 30m of each storey, and the residential building is a row house building with four flats in each row house with two storeys, with the floor area of 7m • 8m of each storey for one flat. The simulations are performed for a typical climatic situation in the respective four countries; Norway, Finland, Germany and Korea.

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". The construction of the "reference year" for the different countries is based on slightly different methods, but this fact has been considered to have no significant effect on the practical result from the simulations.

In this paper we are presenting results from the following places in the four countries; Oslo, Helsinki, Oberhausen and Seoul.

It has to be mentioned that the climate may vary quite a lot within the different countries. Nevertheless, the results should give a good indication on the average situations in the respective countries.

The simulations are performed with the dynamic simulation programme FRES, (Flexible Room climate and Energy Simulator) which is developed at SINTEF/NTNU.

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

- Determination of primary energy savings by DH compared to local heating systems
- Determination of the reduction of electric energy consumption and peak power by DC compared to conventional local cooling plants
- Determinations of environmental benefits from DH&DC compared to local heating and cooling plants

1.4 Simulation results

It is generally known that the density of the heating and the cooling consumption is one of the most critical factors for the feasibility of DH and DC systems. The density in relation to the maximum load demands is also a very critical factor. The reason why can be seen by the following equation, which basically describes the total cost per unit for the delivered energy:

$$C_s = \frac{I_s \cdot a}{\tau} + e_s \qquad (1)$$

C_s = total specific energy cost	(money/kWh)
I_s = specific investment cost	(money/kW)
e_s = specific cost of energy	(money/kWh)
a = annuity factor	(1/year)
τ = equivalent time of max. load	(hours/year)

This equation shows that the findings from the simulated cases could be very fruitfully compared on basis of the values of the figure τ for the respective cases.

In the simulations in this project, the room temperatures are set to 21°C when calculating the heat loads. The cooling loads will be very much depending on the maximum allowed room temperature during the high load periods. Here we have mainly simulated the cooling load presupposing that it will be acceptable to let the room temperature slide from 21°C to 25°C before cooling of the room is introduced. If cooling is not introduced, a cooling load indicates that the room temperature will slide above 25°C.

Figure 1.1 – 1.8 show results from the simulations for the "standard" office building for the stage of 1990 and 2005+. The figures show to the left the so-called **duration curve of the *hourly mean values* of the heating load** as long as we have no cooling load. To the right in the figures the **duration curve of the cooling loads is shown.** Above the zero line to the right we see the corresponding values of the heating loads when we have heating and cooling loads at the same time.

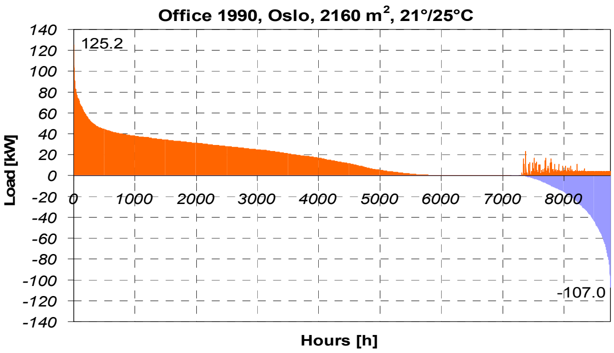


Figure 1.1

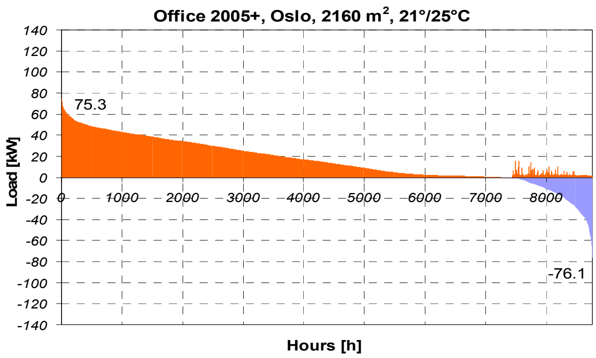


Figure 1.2

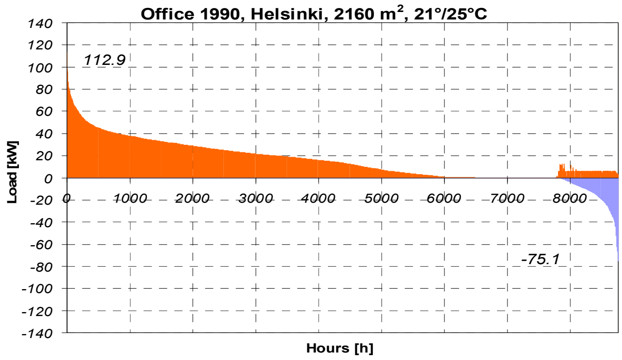


Figure 1.3

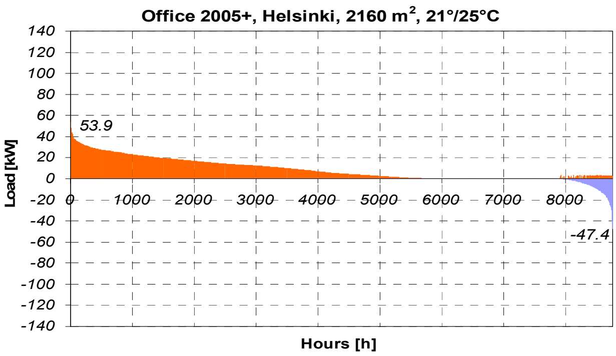


Figure 1.4

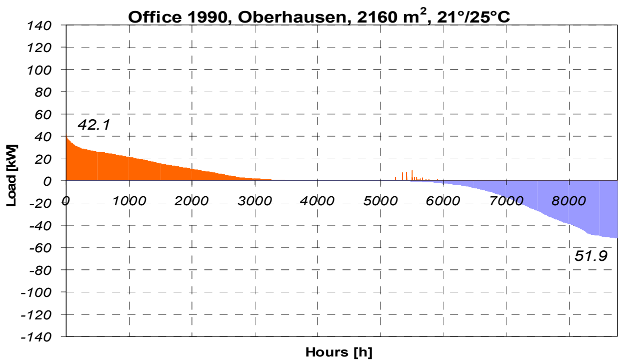


Figure 1.5

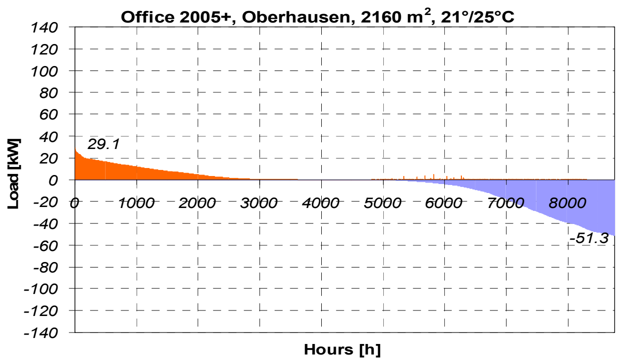


Figure 1.6

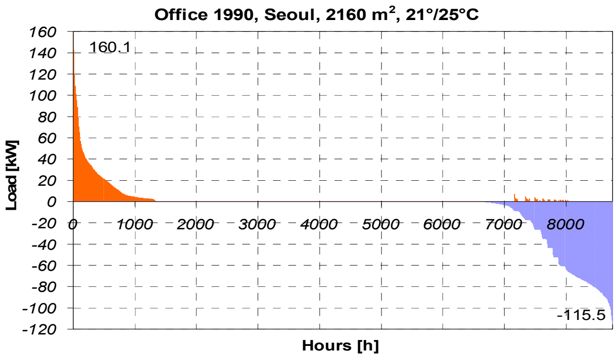


Figure 1.7 (Night setback of the room temperature)

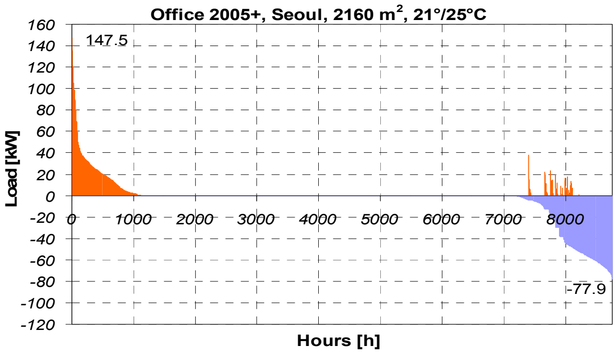


Figure 1.8 (Night setback of the room temperature)

Figure 1.9 shows the **total, yearly heating energy consumption** for the office building in the respective countries, and figure 1.10 shows the **total, yearly cooling energy consumption.**

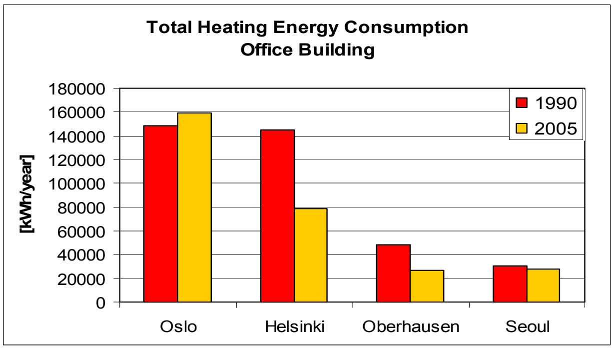


Figure 1.9

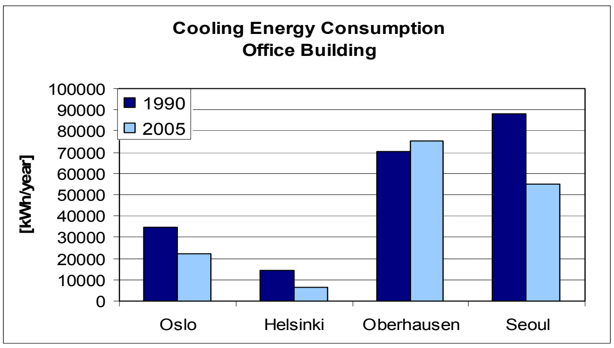


Figure 1.10

Figure 1.11 and 1.12 show the **specific values for the total yearly heating and cooling energy consumption** for the office buildings in the respective countries.

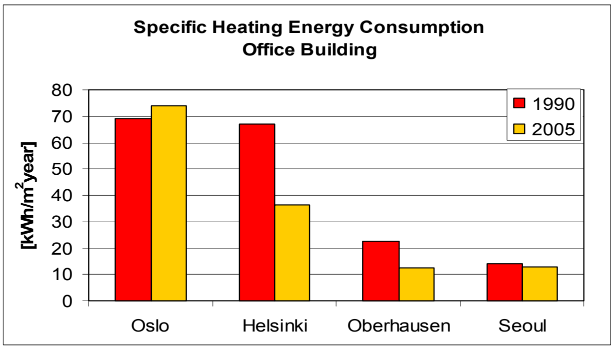


Figure 1.11

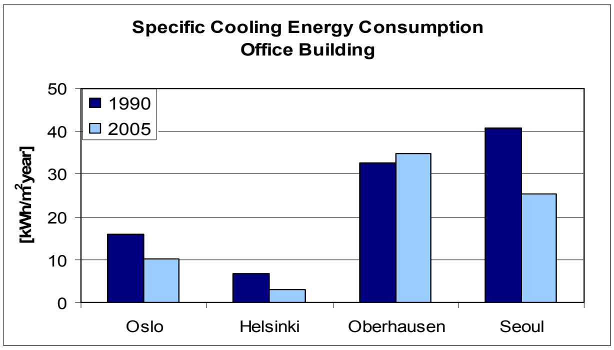


Figure 1.12

Figure 1.13 and 1.14 show the **specific maximum heating and cooling loads** for the office buildings.

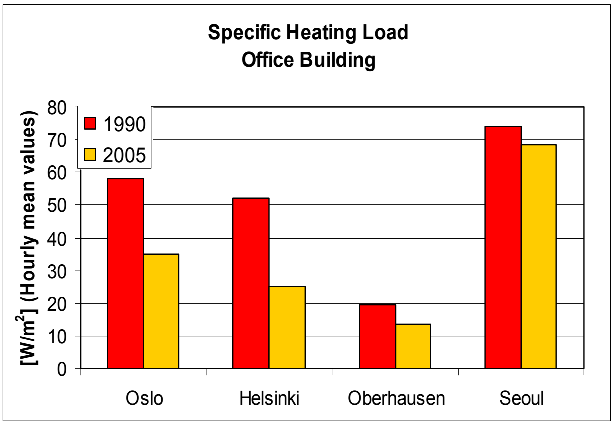


Figure 1.13

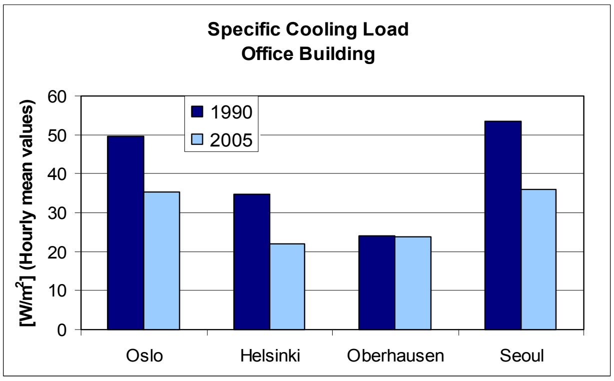


Figure 1.14

The reasons behind 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 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 situation from 1990 to 2005+ is caused by the fact that the effect of an anticipated better insulation is counteracted by in increased ventilation rate.

The figures 1.15 – 1.22 show the results from the simulations for the “standard” residential building for the stage of 1990 and 2005+. The figures show so called **duration curves of the *hourly mean values* of the heating load** as long as we have no cooling load to the left.

To the right in the figures the **duration curve of the cooling loads is shown.** Above the zero line to the right we see the **corresponding values** of the heating loads when we have heating and cooling loads at the same time**.** The values for the residential buildings are average values per flat for the four flats in the simulated row house.

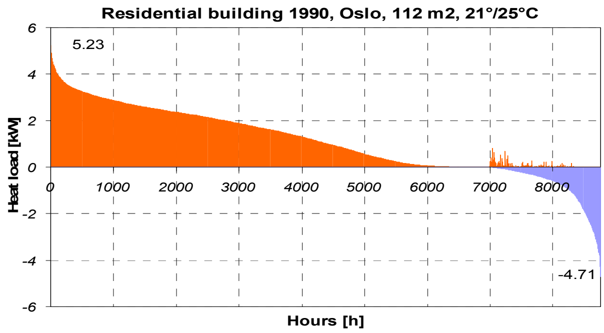


Figure 1.15

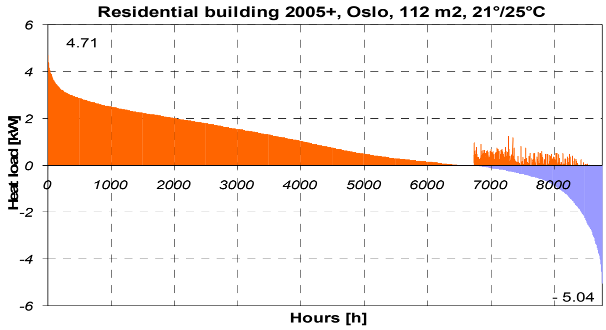


Figure 1.16

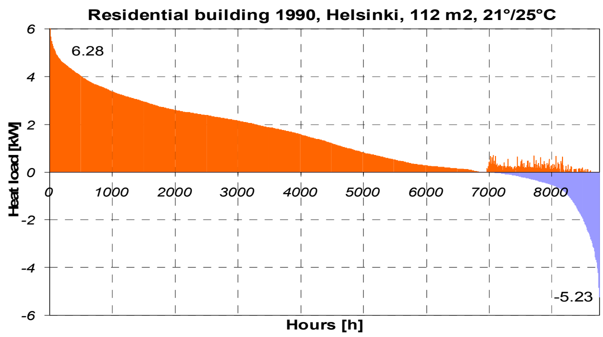


Figure 1.17

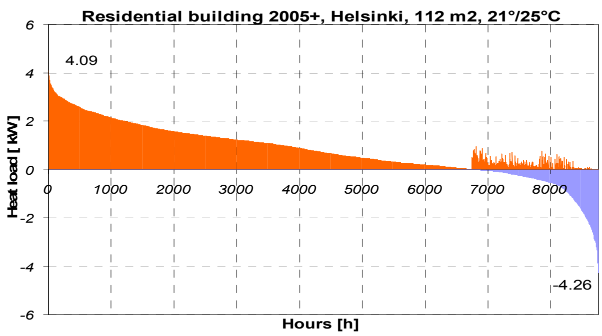


Figure 1.18

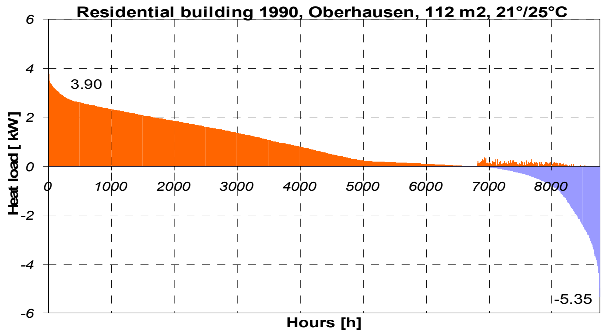


Figure 1.19

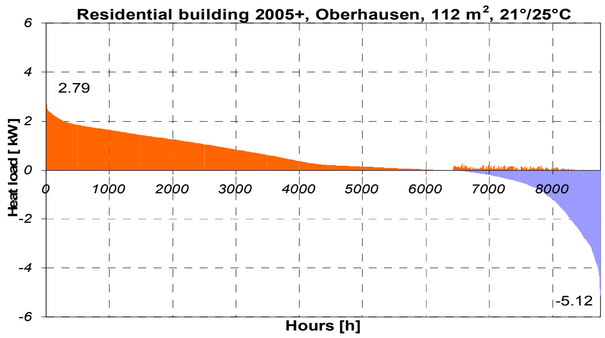


Figure 1.20

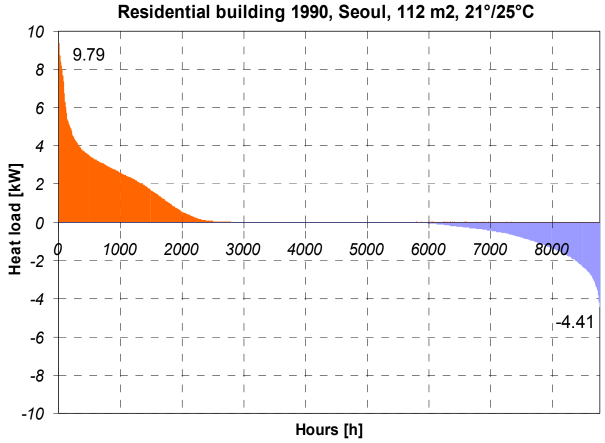


Figure 1.21a (With night setback)

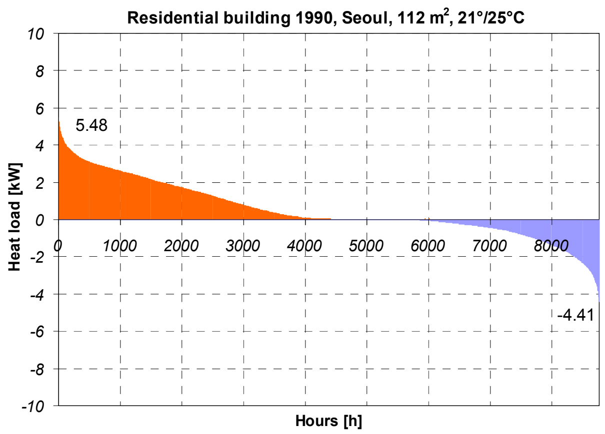


Figure 1.21b (Without night setback)

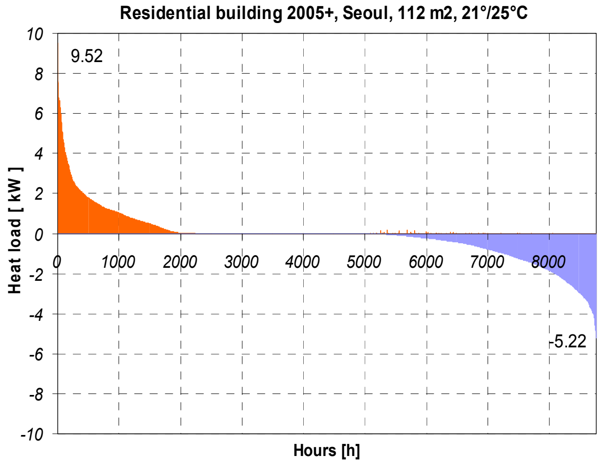


Figure 1.22

The high values of the heating loads in the Seoul cases in figure 1.21a and 1.22 are caused by the fact that night setback of the room temperatures are applied. In these simulations it is assumed that one has heating capacity available to reheat the rooms to the desired value of 21°C during one hour.

The disadvantage of this strategy of running the heat plant is the need of a very high capacity on the heating system to increase the room temperature in the mornings.

To reduce the heating capacity and choose a longer period to reheat the room might be a better solution for the overall economy, even if this strategy will increase the yearly heating consumption.

Figure 1.21b shows the picture with no night setback of the room temperature. The simulations show that the yearly energy consumption will be lowered about 20 % by night setback compared to the consumption with no night setback.

Figure 1.23 shows the **total, yearly heating energy consumption** for the residential building in the respective countries and the figure 1.24 shows the **total yearly cooling energy consumption**.

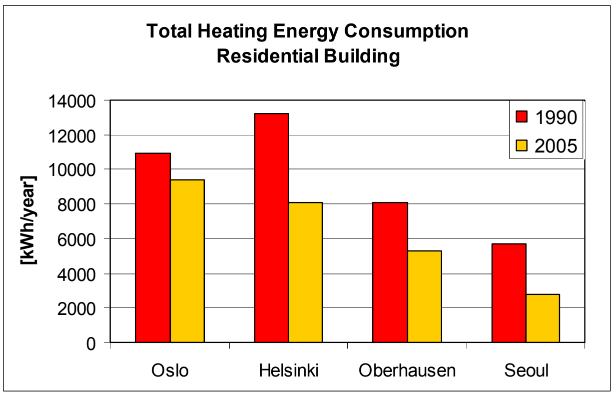


Figure 1.23

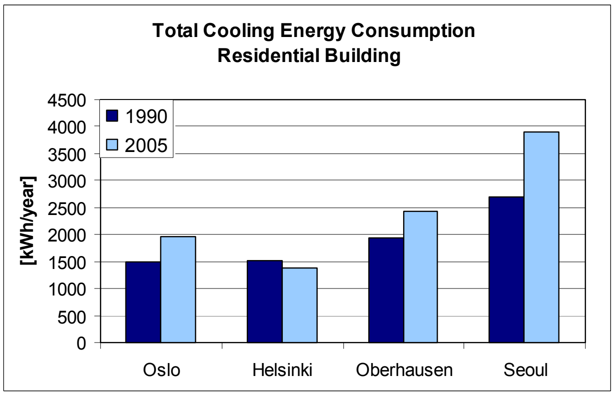


Figure 1.24

Figure 1,25 and 1.26 show the **specific values for the total yearly energy consumption for heating and cooling** for the residential buildings in the respective countries, and the figures 1.27 and 1.28 show the **specific maximum heating and cooling loads.**

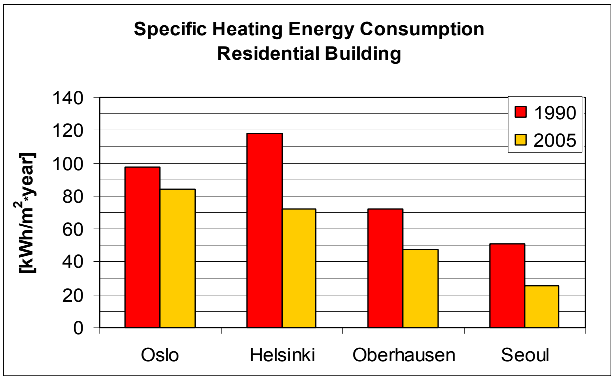


Figure 1.25

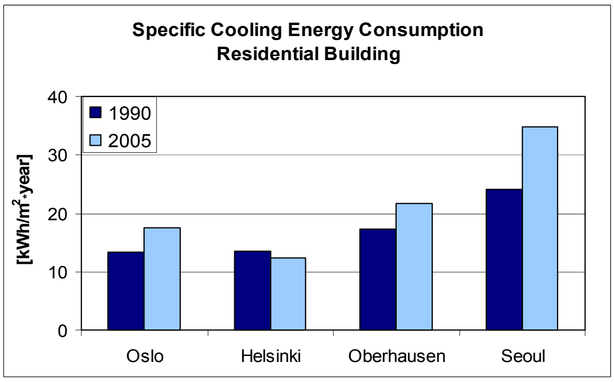


Figure 1.26

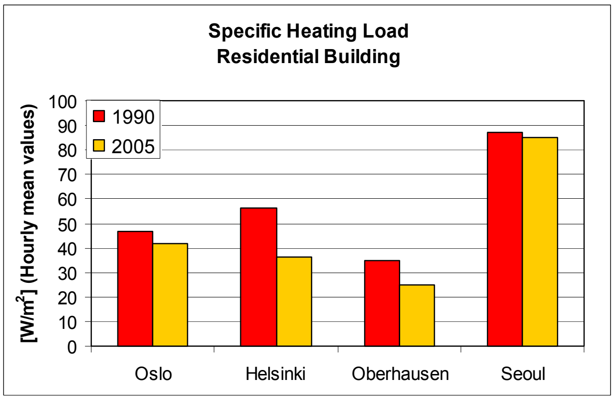


Figure 1.27

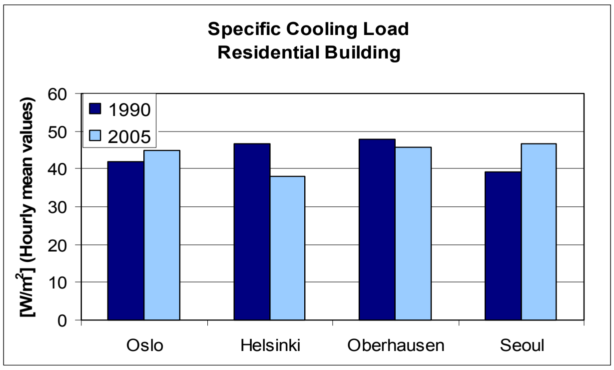


Figure 1.28

1.5 Equivalent time of maximum load

Table 1.1 shows the calculated values of the **equivalent time of maximum load (τ)** for the total heating for the office building.

Office 2160 m^2	Oslo	Helsinki	Oberhausen	Seoul
90-21°/25°	1190	1280	960	190
05-21°/25°	2120	1460	1030	190

Table 1.1 Equivalent time of maximum load for the total heating (hours/year)

Table 1.2 shows the calculated values of the **equivalent time of maximum load (τ)** for the total cooling for the office building.

Office 2160 m^2	Oslo	Helsinki	Oberhausen	Seoul
90-21°/25°	320	190	1330	760
05-21°/25°	290	140	1490	710

Table 1.2 Equivalent time of maximum load for the total cooling (hours/year)

Table 1.3 shows the calculated values of the **equivalent time of maximum load (τ)** for the total heating for the residential building.

Resident. 112 m^2	Oslo	Helsinki	Oberhausen	Seoul
90-21°/25°	2090	2100	2070	590
05-21°/25°	2000	1980	1890	300

Table 1.3 Equivalent time of maximum load for the total heating (hours/year)

Table 1.4 shows the calculated values of the **equivalent time of maximum load (τ)** for the total cooling for the residential building.

Resident. 112 m^2	Oslo	Helsinki	Oberhausen	Seoul
90-21°/25°	320	290	360	610
05-21°/25°	390	320	470	750

Table 1.4 Equivalent time of maximum load for the total cooling (hours/year)

1.6 The effect of sliding room temperature on heating and cooling load and yearly energy consumption

It is quite easy to imagine that the cooling energy consumption will be reduced when we allow the room temperature to slide from 21° C to 25° C before cooling of the room is introduced. For the office building in Oslo we see in the figures 1.29, 1.30 and 1.31 how the picture is changed when decreasing the allowed slide in the room temperature from 21°C to 25°C and down to no slide at all, 21°/21°C.

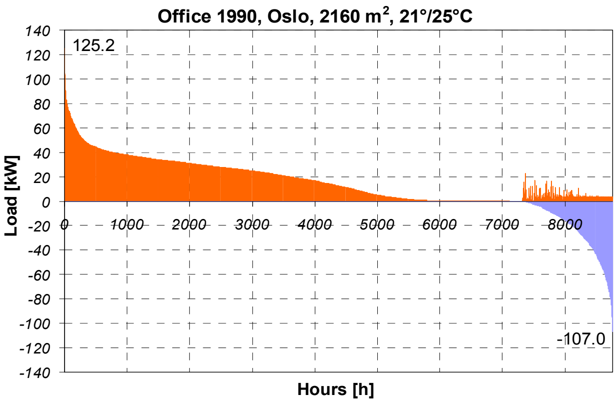


Figure 1.29

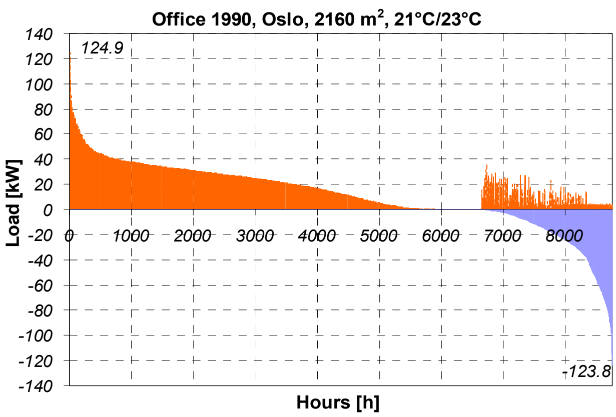


Figure 1.30

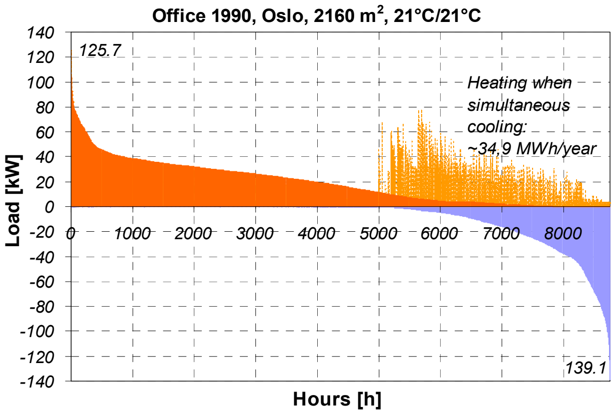


Figure 1.31

The cooling load and the cooling energy consumption increases considerably when we decrease the allowed slide in the room temperature. When no slide in the room temperature is allowed the heating energy consumption will also increase significantly.

Figure 1.32 shows the changes in the **total yearly heating and cooling energy consumption** with different slide of the room temperature and figure 1.33 shows the **specific values for the total yearly heating and energy consumption** for the different conditions.

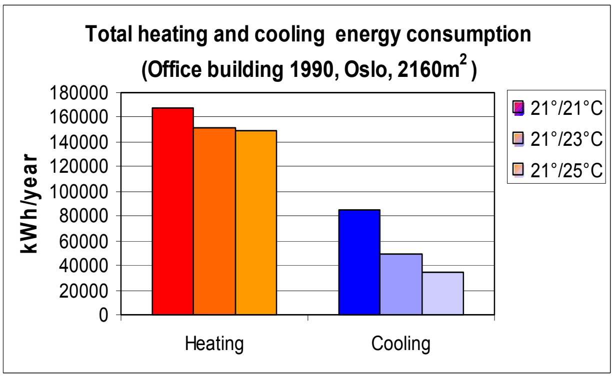


Figure 1.32

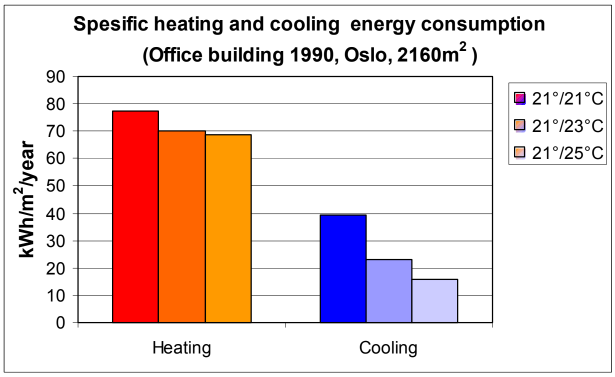


Figure 1.33

1.7. Conclusions

- We have to be aware of the fact that the simulations give only theoretical values. Due to non-optimal construction and operation of the Heating, Ventilating and Air Conditioning systems (HVAC-systems), we will normally observe other values in practice.

Normally the heating and cooling consumption might be considerably higher than the theoretical values. Nevertheless, the theoretical results should give a good picture on the relative values. Figure 1.29-1.33 should give an idea of what may happen when the temperature control system is wrongly adjusted or do not work properly according to the planed intentions. In practice this situation quite often seems to be the case.

- The simulation results will, to some extent, be influenced by choices made by opinion by a small group of individuals based on their best judgement. These choices may of cause in some cases be debated.

- The results show very clearly the typical effects of the different climatic conditions in the different countries. We also see the effects of different strategies of running the heating systems.

- The consequence of changes in the building codes is very clearly demonstrated in the office case from Oslo. The new, Norwegian building code from 1997 demands that the ventilation plant in an office building has to be run throughout day and night due to the contaminants from the building materials.

It is hard to believe that the building codes for example in Finland and Norway will stay as differently in the future as we see in the office case.

- The results from all countries very clearly show the effect of the improved insulation of the walls and the windows from 1990 to 2005+.

- The equivalent time of maximum load seems to stay more or less at the same level in the future except for the office building in Oslo due to the new demands in the new Norwegian building code from 1997.

1.8. Input values for the simulations

A survey of the input values used in the simulations is presented in table 1.5 and 1.6 on the following pages where the following terms are used:

n = data from Norway – Oslo
g = data from Germany – Oberhausen
f = data from Finland – Helsinki
k = data from Korea – Seoul

o = data for office buildings
r = data for residential buildings

90 = typical data for the year 1990
05 = expected data from the year 2005+

1.6 References

SINTEF Flexible Room climate and Energy Simulator (FRES), 1993

Table 1.5 Input values for the simulations – Office building

	U-values				Ventilation plant					Ventilation air flow rate			Shading			
Simu-lation	Outer wall	Roof	Ground floor	Win	VAV	Cool coil	Heat rec eff	Inlet air temp	Duration	Offices	Meet room	Com space	N	E	S	W
o90-n	0.28 W/m²K	0.19 W/m²K	0.28 W/m²K	2.4 W/m²K	No	Yes	0.7	5/20°C - 16/15°C	11 h wd	10 m³/h m²	15 m³/h m²	5 m³/h m²	Cu	VB	VB	VB
o90-f	0.28 W/m²K	0.21 W/m²K	0.22 W/m²K	1.8 W/m²K	No	Yes	0.6	5/20°C- 16/15°C	11 h wd	4.5 m³/h m²	14.3 m³/h m²	1.4 m³/h m²	Cu	VB	VB	VB
o90-g	0.29 W/m²K	0.23 W/m²K	0.38 W/m²K	2.4 W/m²K	No	No	-	-	-	-	-	-	No	VB	VB	VB
o90-k	0.41 W/m²K	0.42 W/m²K	0.68 W/m²K	3.4 W/m²K	No	Yes	Rec air 0.2/0.2	5/20°C- 16/15°C	10 h wd 4 h sat	15.8 m³/h m²	9.5 m³/h m²	6 m³/h m²	Cu	Cu	Cu	Cu
o05-n	0.21 W/m²K	0.14 W/m²K	0.28 W/m²K	1.6 W/m²K	Yes	Yes 07-18	0.7	5/20°C - 16/15°C	All year	7/4.5 m³/h m²	7.4/4.5 m³/h m²	4.5 m³/h m²	VB	VB	VB	VB
o05-f	0.22 W/m²K	0.16 W/m²K	0.16 W/m²K	1.2 W/m²K	Yes	Yes	0.7	5/20°C - 16/15°C	11 h wd	4.5/1.7 m³/h m²	14.3/1.7 m³/h m²	1.4 m³/h m²	VB	VB	VB	VB
o05-g	0,21 W/m²K	0.17 W/m²K	0.38 W/m²K	1.6 W/m²K	No	No	-	-	-	-	-	-	VB	VB	VB	VB
o05-k	0.34 W/m²K	0.34 W/m²K	0.50 W/m²K	1.6 W/m²K	No	Yes	Rec air 0.2/0.2	5/20°C - 16/15°C	9 h wd	21.2/9.1 m³/h m²	10.4/2.6 m³/h m²	7.6/2.6 m³/h m²	VB	VB	VB	VB

	Offices				Meeting room				Common area						Room temperatures	
Simu-lation	Pers	Light	Equip	Dura-tion	Pers	Light	Equip	Dura-tion	Pers	Dur pers	Light	Dur light	Equipt	Dur equip	Temp heating	Temp cooling
o90-n	18/16 pers	15 W/m²	15 W/m²	wd 4/4 h	7 pers	12.5 W/m²	2.5 W/m²	wd 4 h	4/3 pers	wd 4/4 h	9.4/1.3 W/m²	8/16 h	2.5/0.6 W/m²	wd/we	21°C	25/23/21 °C
o90-f	18/16 pers	15 W/m²	15 W/m²	wd 4/4 h	7 pers	12.5 W/m²	2.5 W/m²	wd 4 h	4/3 pers	wd 4/4 h	9.4/1.3 W/m²	8/16 h	2.5/0.6 W/m²	wd/we	21°C	25/23/21 °C
o90-g	18/16 pers	20 W/m²	15 W/m²	wd 4/4 h	7 pers	12.5 W/m²	2.5 W/m²	wd 4 h	4/3 pers	wd 4/4 h	9.4/1.3 W/m²	8/16 h	2.5/0.6 W/m²	wd/we	21°C	25°C
o90-k	27/24 pers	20 W/m²	15 W/m²	wd 6/4 h	8 pers	15 W/m²	2.3 W/m²	wd 4 h	1/0 pers	wd 6/4 h	10/1.2 W/m²	10/14 h	0 W/m²	All year	21/10 °C	25°C
o05-n	18/16 pers	8 W/m²	8.5 W/m²	wd 4/4 h	7 pers	8 W/m²	2 W/m²	wd 4 h	4/3 pers	wd 4/4 h	6/0.6 W/m²	8/16 h	1.9/0.3 W/m²	wd/we	21°C	25/23/21°C
o05-f	18/16 pers	8 W/m²	8.5 W/m²	wd 4/4 h	7 pers	8 W/m²	2 W/m²	wd 4 h	4/3 pers	wd 4/4 h	6/0.6 W/m²	8/16 h	1.9/0.3 W/m²	wd/we	21°C	25/23/21°C
o05-g	18/16 pers	10 W/m²	10 W/m²	wd 4/4 h	7 pers	8.3 W/m²	1.7 W/m²	wd 4 h	4/3 pers	wd 4/4 h	6.3/0.6 W/m²	8/16 h	1.9/0.3 W/m²	wd/we	20°C	-
o05-k	27/24 pers	15 w/m²	9 W/m²	5/4 h	8 pers	10 W/m²	1.8 W/m²	wd 4 h	1/0 pers	wd 4/4 h	7/0.82 W/m²	9/15 h	0 W/m²	wd/we	20/10 °C	26

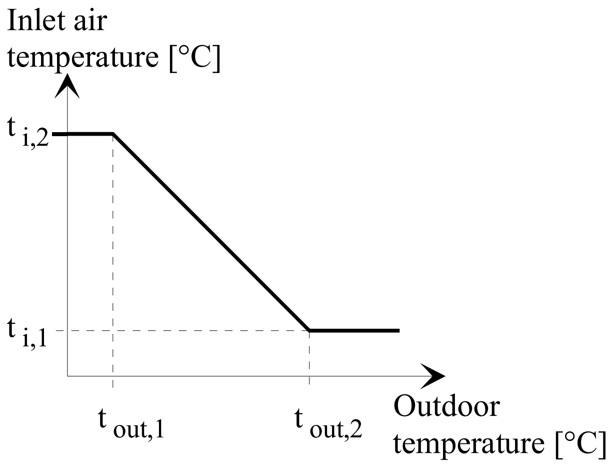
Table 1.6 Input values for the simulations – Residential building

	U-values				Ventilation plant					Air flow rate		Infiltration		Win
Simu-lation	Outer wall	Roof	Ground floor	Win.	H coil	C coil	H rec eff.	In air temp	Op time	Livingr	Bedr	Livingr	Other	Trans-mition
r90-n	0.264 W/m^2K	0.198 W/m^2K	0.283 W/m^2K	2.4 W/m^2K	-	-	-	-	-	[1]100 m^3/h	52 m^3/h	0.6 h^{-1}	0.5 h^{-1}	0.51
r90-f	0.24 W/m^2K	0.209 W/m^2K	0.338 W/m^2K	1.8 W/m^2K	-	-	-	-	-	74/[1]108 m^3/h|	38/[1]76 m^3/h	0.15 h^{-1}	0.15 h^{-1}	0.50
r90-g	0.189 W/m^2K	0.331 W/m^2K	0.359 W/m^2K	2.4 W/m^2K	-	-	-	-	-	-	-	0.75 h^{-1}	0.75 h^{-1}	0.75
r90-k	0.401 W/m^2K	0.574 W/m^2K	0.58 W/m^2K	3.37 W/m^2K	-	-	-	-	-	[1]360 m^3/h	[2]131 m^3/h	0.23 h^{-1}	0.3/[3]0.6 h^{-1}	0.78
r05-n	0.201 W/m^2K	0.143 W/m^2K	0.143 W/m^2K	1.6 W/m^2K	4 kW	2 kW	0.5	21°C	All day	145/[1]245 m^3/h	145 m^3/h	0.18 h^{-1}	0.15 h^{-1}	0.51
r05-f	0.215 W/m^2K	0.152 W/m^2K	0.232 W/m^2K	1.2 W/m^2K	2.5 kW	-	0.5	20°C	All day	74/[1]108 m^3/h	38/[1]76 m^3/h	0.15 h^{-1}	0.15 h^{-1}	0.39
r05-g	0.156 W/m^2K	0.331 W/m^2K	0.359 W/m^2K	1.6 W/m^2K	-	-	-	-	-	-	-	0.5 h^{-1}	0.5 h^{-1}	0.75
r05-k	0.331 W/m^2K	0.333 W/m^2K	0.335 W/m^2K	1.75 W/m^2K	-	-	-	-	-	[1]360 m^3/h	[2]131 m^3/h	0.23 h^{-1}	0.3/[3]0.6 h^{-1}	0.78

	Livingroom						Bedroom				Bathroom				
Simu-lation	Pers	Light	Equip	Dura-tion	Temp heat	Temp cool	Pers	Duration	Temp heat	Temp cool	Pers	Light	Equipt	Duration	Temp
r90-n	4 pers	200 W	500/50 W	1/6 h wd 2/6 h we	21°C	25°C	4 pers	8 h wd 10 h we	21°C	25°C	1 pers	75 W	100 W	1 h wd 1 h we	22°C
r90-f	4 pers	200 W	500/50	1/7 wd 2/7 we	21°C	25°C	4 pers	7 h wd 9 h we	21°C	25°C	1 pers	75 W	100 W	1 h wd 1 h we	22°C
r90-g	4 pers	200 W	500/50 W	1/7 wd 2/7 we	21°C	25°C	4 pers	7 h wd 9 h we	21°C	25°C	1 pers	75 W	100 W	1 h wd 1 h we	24°C
r90-k	4 pers	204 W	660/50 W	1/4 we 1/5 sat 2/5 sun	[4]21°C 15°C	25°C	4 pers	8 h wd+sat 10 h sun	[4]21°C1 15°C	25°C	1 pers	120 W	100 W	1 h wd 1 h we	[4]21°C 15°C
r05-n	4 pers	150 W	350/50 W	1/6 wd 2/6 we	21°C	25°C	4 pers	8 H wd 10 h we	21°C	25C	1 pers	75 W	80 W	1 h wd 1 h we	22°C
r05-f	4 pers	150 W	350/50 W	1/7 wd 2/7 we	21°C	25°C	4 pers	7 h wd 9 h we	21°C	25°C	1 pers	75 W	80 W	1 h wd 1 h we	22°C
r05-g	4 pers	150 W	350/50 W	1/7 wd 2/7 we	21°C	25°C	4 pers	7 h wd 9 h we	21°C	25°C	1 pers	75 W	80 W	1 h wd 1 h we	24°C
r05-k	4 pers	156 W	460/50 W	1/6 we 2/4 we	[4]21°C 15°C	[5]25°C 35°C	4 pers	8 h wd+sat 10 h sun	[4]21°C1 5°C	[5]25°C 35°C	1	120 W	80 W	1 h	[4]21°C 15°C

Remarks to Table 1.5:

- The inlet air temperature is given as $t_{out,1}/t_{inlet,1}$ - $t_{out,2}/t_{inlet,2}$, where the different temperatures are illustrated in



- The equipment gain is based on used offices, i.e. if 18 persons in the offices and the equipment gain is 150 W/office, the total equipment gain per floor is
  18*150W=2700 W
- The lighting gain is based on used offices, i.e. if 18 persons in the offices and the lighting gain is 150 W/office, the total lighting gain per floor is
  18*150W=2700 W
- Varying persons in the offices during the working hours are moved to the meeting room. If the number of persons in the office is 18/16 pers., there are 16 persons in the offices during the meeting, while there are 18 persons in the offices if there is no meeting. The same yields for persons in the common area.
- In the column for duration of the ventilation plant, wd stands for week days, we stands for week ends, while sat stands for Saturday.
- In the column for shading, *Cu* stands for curtains, *VB* stands for venetian blinds
- Korea has re-circulation of air (Rec.air) with a minimum fresh air part of 20% in the heating modus and minimum 20% fresh air in the cooling modus (0.2/0.2).
- VAV-systems in these simulations are ventilation systems where the air flow varies with the number of persons in the room. In buildings with VAV-systems, the air flow is given for occupied rooms and empty rooms.

Remarks to Table 1.6:

- In the columns for *Duration*, "wd" stands for week days, "we"stands for week ends, while "sat" stands for Saturday. All duration's are per 24 hours.
- The air flow rate might be separated in two, which means that the air flow rate is separated in two different flows during the day, see [1].
- If an air flow rate is indicated without a ventilation unit, the room is ventilated directly with outside air, for instance through a flapper valve
- All buildings have curtains as shading in the windows.
- The equipment gain is separated in two, the left part yields for the hours shown in the column *Duration*, the other part for the remaining hours.
- The duration for the occupation, lighting gain and equipment gain is separated in two, one in the morning and one in the evening. The total duration during the day is the sum of the two numbers.

1 The kitchen ventilator air flow. It is only used one hour while making dinner. The ventilation air flow to the kitchen ventilator is added on the ventilation air flow that is supplied to the livingroom/kitchen.
2 The ventilation air flow ventilate the bathroom while it is occupied.
3 The bathroom has an infiltration rate of 0.6 h^{-1}.
4 The heating set point temperature is set low during the summer time to avoid heating in the summer time.
5 The cooling set point temperature is set high during the wintertime to avoid cooling in the wintertime.