SPACE HEATING AND COOLING DEMAND OF BUILDINGS IN THE PERSPECTIVE OF CLIMATE CHANGE IN COLD AND HOT CLIMATES – IS THIS A RISK?

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Abstract

The global rise in temperature due to climate change is undisputed today. This will lead to a decrease in space heating demand in winter but to an increase in cooling demand in summer. In the following contribution, the space heating and cooling demand of a residential building for climates of Innsbruck and Rome for different climate scenarios (IPCC (2014), RCP Scenarios) and time horizons are calculated and analyzed. Required changes for building codes and standards as for climate change are sketched. In conclusion, the increase of the cooling demand can be met with slightly oversized cooling systems in hot climates (e.g., Rome), whereas in cold climates (e.g. Innsbruck) the increase can be kept very low by passive measures. The increase in electricity demand for cooling in summer coincides with the comparable high summer-production of PV. The reduction of energy demand in winter will help in reducing the gap of low PV electricity production in winter. This is also valid for mountainous countries like Austria with high hydro power availability in summer due to snow melt.

Keywords: climate change, scenarios, building heating demand, building cooling demand

1. Introduction

The global rise in temperature due to climate change is undisputed today. For buildings in Central and South Europe, this means that the need for space cooling will increase. On the other hand, space heating requirements in winter will be reduced also in northern Europe or is even not needed any more in Middle Europe. Electricity will be one of the main energy carriers in future energy systems. By the use of heat pumps for heating and cooling for a fossil free energy system the electricity will be used highly efficient.

Sufficient photovoltaic electricity will be available in summer if the current strong installation increase is carrying on. In winter, electricity from wind energy will be available in Europe due to expected massive expansion of installations in the North Sea, but photovoltaics naturally will only make a small contribution. Hydropower tends to be at its maximum in end of spring due to snow melt and at its minimum at the end of winter due to snow fall during winter. Therefore, shifting the energy demand from heating energy in winter to cooling energy in summer should not be classified as a risk in climate change impact studies. In the following contribution, the space heating and cooling demand of a residential building for climates of Innsbruck and Rome for different climate scenarios (IPCC (2014), RCP Scenarios) and time horizons are calculated and analyzed and proposals for changes for building codes and standards according to expected climate change are sketched.

2. Boundary conditions for the simulation

2.1. Building definition

The residential building used in this study was defined in detail in Dott et al (2013) for IEA SHC Task 44 / HPP Annex 38 as SFH45 (Single Family House with approx. 45 kWh/m^{2}a space heating demand in 2020 Innsbruck climate) and is widely used in scientific case studies. It represents a 2-storey single family building with about 140 m² net area with about current new or renovated German and Austrian insulation standards (U-

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values: external wall 0.29 W/m²K, roof ceiling 0.20 W/m²K, ground floor 0.17 W/m²K, windows 1.1 W/m²K and g-value of 0.62) and an air exchange rate of 0.4 h^{-1}. All windows in the buildings are equipped with venetian blinds (shading coefficient 0.25) which are activated, if all of the following conditions are fulfilled:

- *the global horizontal irradiation exceeds 300 W/m²,*
- *the indoor room temperature is higher than 22.8°C and*
- *the 24 hour moving average ambient temperature is greater than 12°C.*

A free driven night ventilation mode for passive cooling, realized by tilted windows, is activated for all buildings if all of the following conditions are met:

- *time between 9 p.m. and 8 a.m.,*
- *average ambient temperature of the last 24 hours above 12°C,*
- *room temperature above 24°C*
- *and actual ambient temperature at least 2K below the actual room temperature.*

Schedules for occupancy and electric gains were defined. The set temperature for space heating was 21°C and for cooling 26°C. The building was simulated using TRNSYS 17 (2014). Figure 1 shows a schematic drawing of the building.

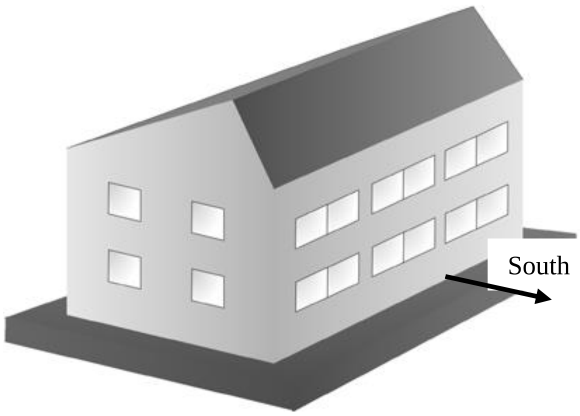

Fig. 1 Simple view of the simulated house (showing South and West facades)

2.2. Climate definition

The two different locations of Innsbruck/Austria (cold climate) and Rome/Italy (hot climate) have been used to represent a climate span from middle to southern Europe. Using the software [Meteonorm 8.2.0, 2020] the building simulations were carried out for today's climate and the three different Scenarios of the Intergovernmental Panel on Climate Change, scenarios RCP 2.6, RCP 4.5 and RCP 8.5 for the year 2050 IPCC (2014). Additionally, calculations for the RCP scenario 8.5 for the year 2080 as extreme condition, with higher yearly average temperature of 4.3°C in Innsbruck and 3.9°C in Rome, were done. In the RCP 4.5 and RCP 8.5 scenarios the temperature will still rise after 2080. Figure 2 shows the annual emissions and the prognosed temperature rise of the different scenarios until the year 2100. RCP means Representative Concentration Pathway and describes several possibilities, how the emission of greenhouse gases will develop. The current worldwide development is close to the higher RCP scenarios.

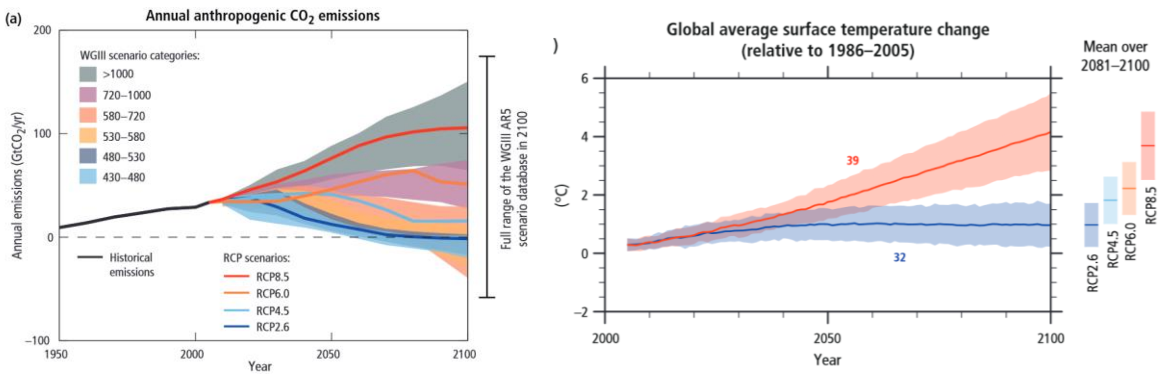

Fig. 2 Anthorpogenic (human made) CO2 emissions and global average earth surface temperature rise for the different RCP scenarios (IPCC, 2014)

3. Results and Analysis

Figure 3 (Innsbruck) and Figure 4 (Rome) and Table 1 show the results for the specific heating and cooling energy demand in kWh/m²a as well as the maximum load (power demand, size of heating and cooling device) for both climates in kW. The energy demand is responsible for the operating costs and the heat/cooling load for the sizing of the heating/cooling devices and therefore the investment costs. Additionally, in the legend of Figure 3 and Figure 4 the seasonal temperature rise compared to today is given for every calculation.

It can be seen that for the cold climate example of Innsbruck, the specific space heating demand (kWh/m²a) is decreasing more than the cooling demand increases with increasing seasonal temperatures. Until 2050 there is more or less the same reduction of space heating demand by 7 kWh/m²a (or about 15%) for all climate scenarios. The space cooling demand is increasing between 1–4 kWh/m²a. Here the percentage increase is very high, as only very low cooling occurs in the current climate. Even in 2050 the cooling demand still is more or less negligible, because only a few days are affected where the room temperature becomes higher than 26°C. Of course, if night ventilation and shading as described in chapter 2.1 are not used, the cooling demand would be much higher. For the RCP 8.5 scenario for the year 2080, the cooling demand is already at about 10 kWh/m²a and active cooling is possibly needed. The maximum space heating load in the different scenarios reduces slightly from 4.4 kW to 3.9 kW as the cooling load increases from 0.7 kW to 2.0 kW.

Both demands can be covered by the same reversible heat pump, that can switch from heating to cooling. For this ratio of heating and cooling demand the size of the heat pump is defined by the heating load, it’s cooling capacity is lower for the same heat source and heat sink temperatures, but the needed cooling power is even lower (ref. to equation1).

$$\dot{Q}_{cooling} = \dot{Q}_{heating} \cdot \left(\frac{(COP_{heating}-1)}{COP_{heating}}\right) = \dot{Q}_{heating} \cdot \left(\frac{COP_{cooling}}{COP_{heating}}\right) \quad \text{(eq. 1)}$$

$$COP_{heating} = \frac{\dot{Q}_{heating}}{P_{el}};\ COP_{cooling} = \frac{\dot{Q}_{cooling}}{P_{el}}$$

with

$\dot{Q}_{cooling}$	[kW]	Maximum Cooling Load
$\dot{Q}_{heating}$	[kW]	Maximum Heating Load
P_{el}	[kW]	Electricity demand for the maximum heat load
$COP_{heating}$	[-]	Heating Coefficient of Performance
$COP_{cooling}$	[-]	Cooling Coefficient of Performance

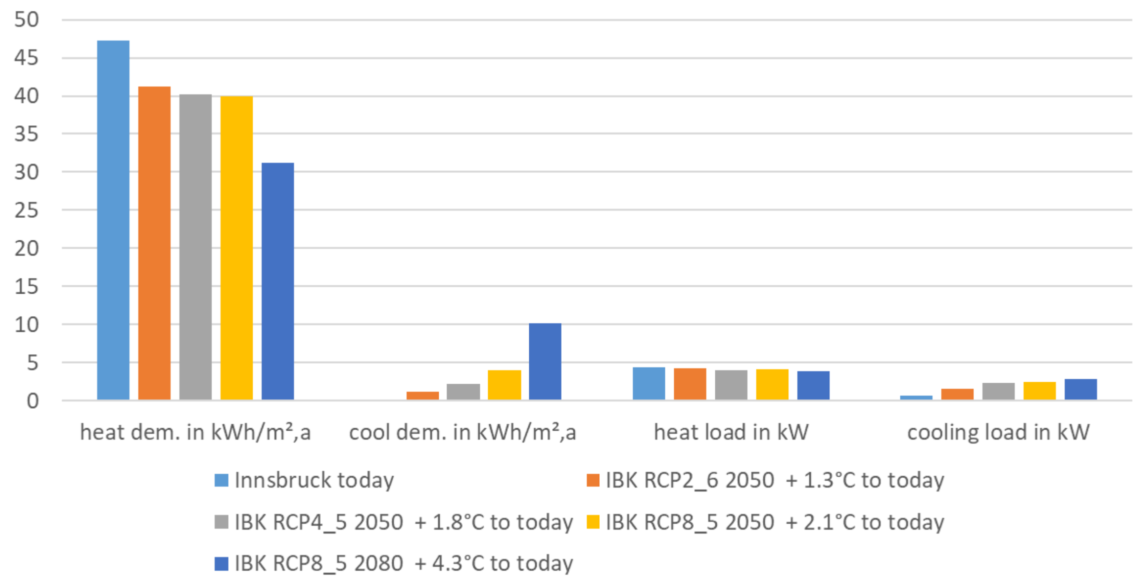

Fig. 3 Innsbruck, residential building 140 m², specific heating/cooling energy demand and load for different climate scenarios. Today: spec. heating demand 47.3 kWh/m²a, spec. cooling demand 0.1 kWh/m²a

For the hot climate (Figure 4 and Table 1), the space heating demand is reduced from 12.2 kWh/m²a to 3.0 kWh/m²a for RCP 8.5 in the year 2080, which means nearly no need for space heating any more. The cooling demand increases from 18 to 40 kWh/m²a. The cooling demand increases more than the heating demand reduces. The heating load reduces insignificantly from 2.2 kW to 1.5 kW and the cooling load increases from 2.6 to 3.5 kW (increase of 34%, RCP 8.5, 2080). To match the 2050 cooling demand for all climate scenarios, cooling machines bought today should be oversized by about 20 % to account for climate change until 2050 with a cooling load of around 3.1 kW. Reversible heat pumps used for space heating and cooling should be sized according the cooling load.

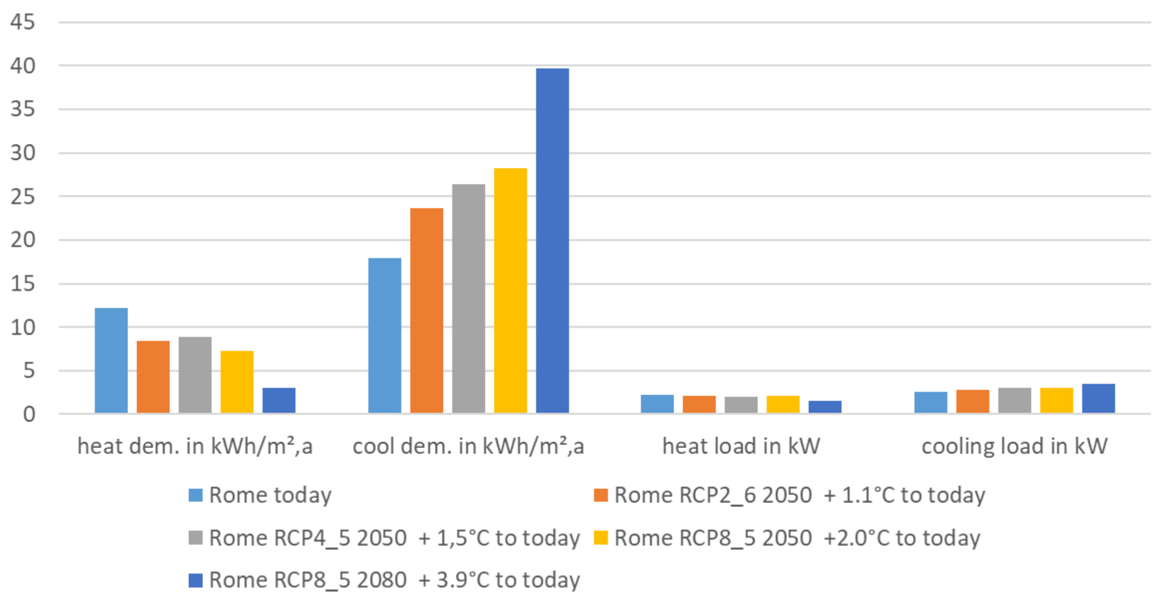

Fig. 3 Rome, residential building 140 m² specific heating/cooling energy demand and load for different climate scenarios. today: spec. heating demand 12.2 kWh/m²a, spec. cooling demand 18.0 kWh/m²a

Tab. 1: Heating and Cooling demand and maximum load for the different climates and the locations Innsbruck and Rome

Loation/	Climate	Heating	Cooling
		Spec. demand / max. load kWh/m²a / kW	Spec. demand / max load kWh/m²a / kW
Innsbruck	**Today**	**47.3 / 4.4**	**0.1 / 0.7**
	RCP 2.6, 2050	41.2 /4.2	1.3 / 1.5
	RCP 4.5, 2050	40.2 / 4.0	2.2 / 2.3
	RCP 8.5, 2050	39.9 / 4.0	4.0 / 2.5
	RCP 8.5, 2080	31.3 / 3.9	3.9 / 2.9
Rome	**Today**	**12.2 / 2.2**	**18.0 / 2.6**
	RCP 2.6, 2050	8.4 / 2.1	23.7 / 2.8
	RCP 4.5, 2050	8.4 / 2.1	26.4 / 3.0
	RCP 8.5, 2050	7.2 / 2.1	28.2 / 3.1
	RCP 8.5, 2080	3.0 / 1.5	39.8 / 3.5

The primary focus for all climates is on the use of passive measures. For the heating period a very good thermal insulation and three pane windows, main window areas facing south are keeping their importance. In the cooling period, external gains from the sun should be kept out of the building by a good insulation of roofs and facades as well as active movable shading systems (in the south also overhangs may help, but they increase space heating demand in winter) and night ventilation (as being used in the simulation). Such passive measures have to be kept or, if currently not there they have to be included, in the building codes to keep the cooling demand low despite of rising temperatures due to climate change.

To keep costs low for the building owners/users, the dual use of a system for heating and cooling, both in terms of generation and delivery to the buildings, are needed (e.g. reversible heat pump with space heating/cooling ceiling for water driven systems or combined ventilation/space heating and cooling outside air systems as split or multi-split systems). Heating systems based on fossil fuels (oil, natural gas) will be forbidden in most of the countries. If biomass driven or direct electric heating systems are used, additional cooling systems have to be installed thus increasing the costs. If radiators or floor heating systems are used for room heating, additional cooling delivery systems have to be installed, again increasing the HVAC investment costs. The cheapest solution would be integrated ventilation/heating/cooling all-in-one systems which are under development. They can be used especially in energetically well designed (see above) buildings either centrally or decentralized.

The building codes and standards of HVAC systems have to be adapted accordingly, in order to build climate-fit cheap systems already today. Planners and HVAC installers have to be trained to assure high quality and low cost systems.

In conclusion the climate change is not causing mayer problems in building energy demand, as long as passive and active measures to reduce the demand are consequently applied in the buildings. The increase of the very low space cooling demand in cold climates can be met with reversible heat pumps sized on current heating demand. Additionally, in cold climates the increase of cooling load still can be handled by consequent use of passive measures in residential buildings, offices and hotels. The heating demand in hot climates will be reduced but the cooling demand will be increased by a larger extend. However, the increase in electricity demand for cooling in summer coincides with the production of PV or partly hydro power. In winter, the reduction of the space heating demand will help in reducing the energy demand.

4. References

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Appendix: Nomenclature

HPP	Heat Pump Programme of the International Energy Agency
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
RCP	Representative Concentration Pathway, Names of IPCC scenarios
SFH	Single Family House
SHC	Solar Heating and Cooling Program of the International Energy Agency