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Impact of CH2018 Climate Change Scenarios for Switzerland on today's Swiss building stock

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Abstract. The energy demand of buildings heavily depends on outdoor temperature. Current climate change projections suggest an increase in annual mean temperatures of up to 5.4 °C for Switzerland until the end of the century. In this study, an existing bottom-up building stock model is coupled with the latest spatio-temporal climate change projections. This allows for simulating the heat demand for each Swiss building for three different climate change scenarios and three periods. It is found that while space heat demand can decrease up to 33% by the end of the century, the need for air conditioning can arise. Furthermore, the impact of climate change differs between regions in Switzerland.

1. Introduction

The demand for heating and cooling in buildings is responsible for a significant share of the worldwide total energy demand and thus of the global greenhouse gas emissions [1]. While building heating and cooling loads depend mainly on thermo-physical properties (e.g. level of insulation) of a building, they are also strongly influenced by outside temperature [2, 3]. This is particularly important in the context of global warming and might thus substantially impact current building heating and cooling profiles.

Recently released climate change simulations indicate that Switzerland is becoming drier and hotter and even an increase in the average temperature of up to 5.4 °C is possible until the end of the century [4]. The simulations notably indicate that there will be regional differences with regard to the increase in temperatures. A deep understanding of the impact of climate change on the building stock is important for policymakers in order to prioritize and plan constructive and targeted environmental refurbishment strategies of building stocks that are tailored to specific regions. Climate change can also have a direct impact on heat energy suppliers. For example, district heating networks depends heavily on the locally available heat demand.

This study aims to model and understand the impact of increasing global temperatures on the energy demand of the Swiss building stock. For Switzerland, a Geographic Information System (GIS) based bottom-up building stock model is available and has been applied and evaluated to Switzerland's current situation [5]. By coupling this model with the climate change simulations we are able to calculate the impact of different climate change projections and periods on todays' building stock.

Table 1. Periods used by the CH2018 initiative [4, p.225]

Period	Years
Ref	1981 - 2010
2030	2020 - 2049
2060	2045 - 2074
2085	2070 - 2099

2. Data

In this work, climate change is accounted for by using the recently released climate model results developed in the scope of the Swiss Climate Change Scenarios 2018 initiative (CH2018) [4]. These scenarios are based on the following three representative concentration pathway (RCP) greenhouse gas projections of the Intergovernmental Panel on Climate Change (IPCC): 2 °C-compliant mitigation (RCP2.6), 2 °C-noncompliant mitigation (RCP4.5) and unabated emissions (RCP8.5) [6].

For each of the RCP the CH2018 scenarios consist of a set of climate change simulations based on different climate models from the EURO-CORDEX[1] collection. Each of the simulations is bias corrected using quantile mapping [7]. In total, the ensemble of the CH2018 scenarios includes 68 simulations: 12 simulations for RCP2.6, respectively 25 and 31 simulations for RCP4.5 and RCP8.5. For each simulation, the CH2018 dataset [8] provides gridded data with a 2 by 2km spatial and daily temporal resolution for the period 1981 to 2099. While the dataset provides multiple variables, such as daily min/max temperatures or wind speed, in this study, only the daily mean temperatures are used.

As the mean temperatures are only provided with a daily resolution, we aggregated the temperature to monthly mean temperatures for the 4 periods shown in table 1 for each of the 68 simulations. These periods correspond to the periods used in the CH2018 technical report [4, p. 22].4 Figure 1 shows the mean temperatures of the different climate models grouped by the RCP scenarios and periods. Each of the circles represents the yearly mean for one of the simulations and periods. The RCP2.6 scenario has the smallest increase of mean temperatures compared to the reference period. An increase in the mean temperature until the 2030 period is projected while for the periods 2060 and 2085 the mean temperature roughly stays at the same level. In contrast, the simulations for the RCP8.5 scenario project an increasing mean temperature until the end of the century.

3. Methods

To simulate the heat demand of buildings, we utilize an existing building stock energy model [5]. This bottom-up model simulates the heat demand for each building using a modified SIA 380/1 heat model [9] with a monthly resolution. The model derives input parameters of the heat model, such as building geometries and volumes, outside temperature as well as solar irradiation, from spatio-temporal data and GIS. The use of spatial data allows the model to simulate location-specific heat demands for each building. As not all parameters are available at a building level, a Monte Carlo simulation is performed. Thereby, parameters that cannot be derived from spatial data, such as room temperature or ventilation behavior, are sampled from probability

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[1] `www.euro-cordex.net`

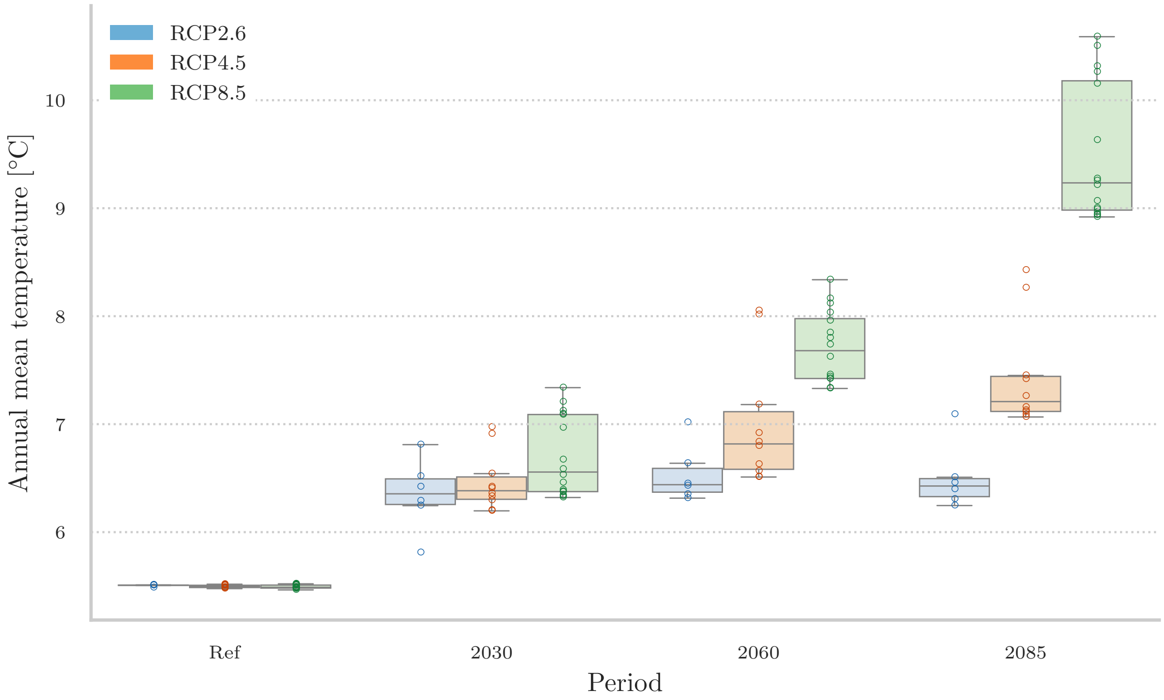

Figure 1. Annual mean temperature of the climate models included in the CH2018 for different RCP projections and periods.

distributions. This also includes thermo-physical parameters of building components which are sampled from historical data and renovation probabilities.

For this work, we have extended the approach as follows. We perform the simulation for all Swiss residential buildings, as opposed to 1965 buildings in [5]. For each period, RPC scenario and building we perform a Monte Carlo simulation with 500 simulations. In each of the simulation runs, in addition to the above-mentioned parameters one of the before mentioned aggregated climate simulations (shown as circles in figure 1) is selected uniformly, and the temperature values for the location of the buildings are extracted. It is important to note that for one building, we obtain not one heat demand value, but a distribution of heat demands. In total, our model contains 1.62 million buildings. Thus, in this work we simulated the heat demand 8129 million times.

4. Results

Figure 2 shows the yearly estimated space heat energy demand for different periods and different RCP scenarios. For each combination, the plot shows the median heat demand (black line), the interval between the 25th and 75th percentiles (dark colored area) and the interval between the 5th and 95th percentiles (light colored area). The numbers next to the medians indicate the relative change compared to the reference period. It can be seen that space heat demand decreases for all periods and RCP scenarios. As expected from figure 1, with a relative change of -33.9% the space heat demand is the lowest for the period 2085 and the RCP8.5 projection. In contrast, the RCP2.6 projection only has a reduction in space heat demand of -9.5% for the same period.

In figures 2 and 4 we only considered space heat demand. Figure 3 shows the monthly energy demand including cooling for the period 2085. It can be seen that the energy demand for the

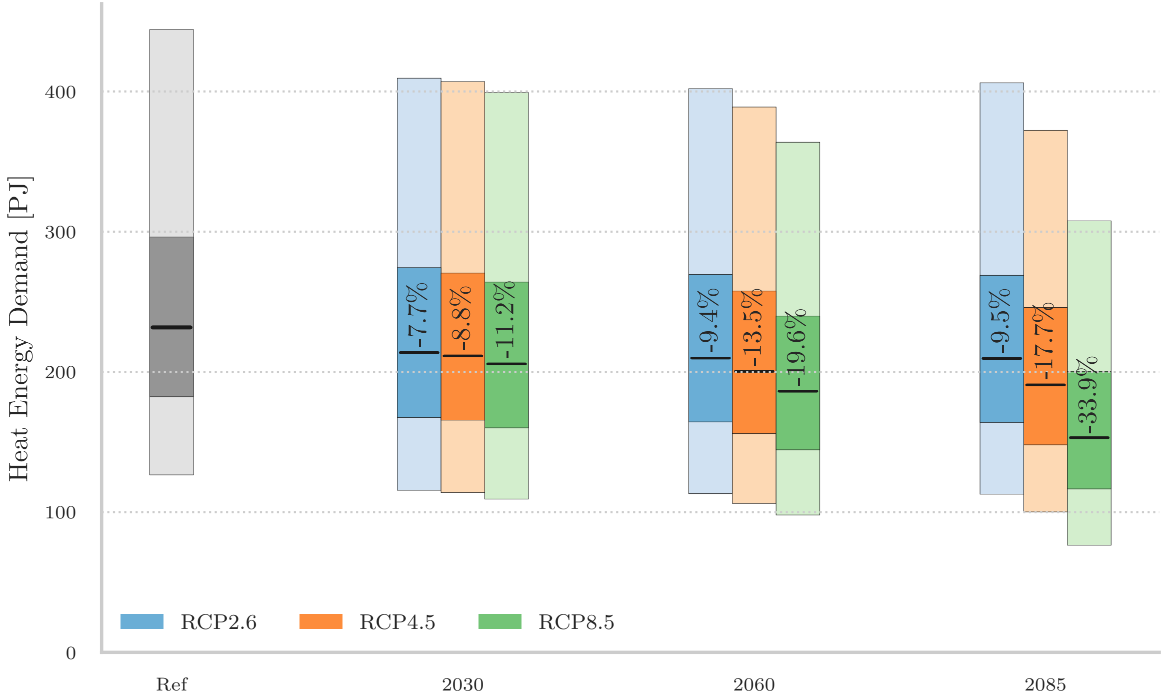

Figure 2. Heat demand for different periods and RCP scenarios.

summer months from June to September can be negative. It is important to note that the SIA380/1 heat demand algorithm is designed only to calculate space heat demand and is not suitable for cooling demand calculations. Normally, negative loads are cut off in the SIA380/1, however, we illustrate them to give an indication of potential cooling loads that can be expected.

The spatial distribution of the relative change in heat demand is not uniformly distributed across Switzerland, as seen in figure 4 for the period 2085 and the RCP8.5 scenario. The highest decrease can be observed in the Alpine valleys as well as in the east and south of Switzerland. However, it should be noted that this scenario and period is the most extreme case and thus the pattern is more distinctively visible compared to the other periods and scenarios.

5. Discussion

The service life of a building is typically more than half a century [10]. Although buildings can be retrofitted multiple times during their lives, the building renewal rate is currently only at around one percent [10]. Thus, the policies in place today will affect the building stock energy demand for decades. Understanding the impact of climate change of today's building stock is vital for defining adequate policies. This work is a step towards understanding the spatio-temporal impact of climate change on buildings in Switzerland. While this study could quantify the spatial impact on today's building stock, more work is needed to fully understand the impact of climate change fully. For example, this study does not consider the creation of new, respectively replacement of old buildings as well as future retrofit scenarios. Especially for the periods 2060 and 2085, a substantial change in the building stock might be possible. Additionally, we focused mainly on space heat demand. Although space heat demand is likely to decrease in the next decades, the energy demand for cooling might rise in the future as the need for air conditioning can grow due to the increased mean temperature. In future work, cooling energy demand needs to be investigated with appropriate models. For a more accurate

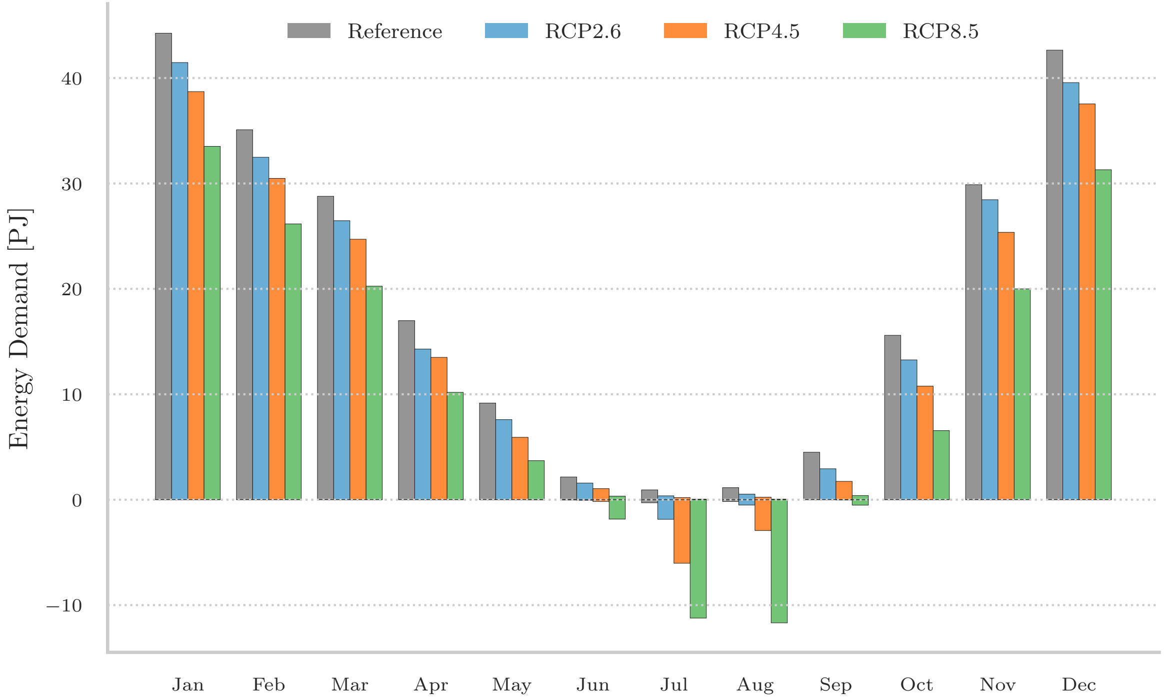

Figure 3. Monthly median energy demand for the reference period and the period 2085.

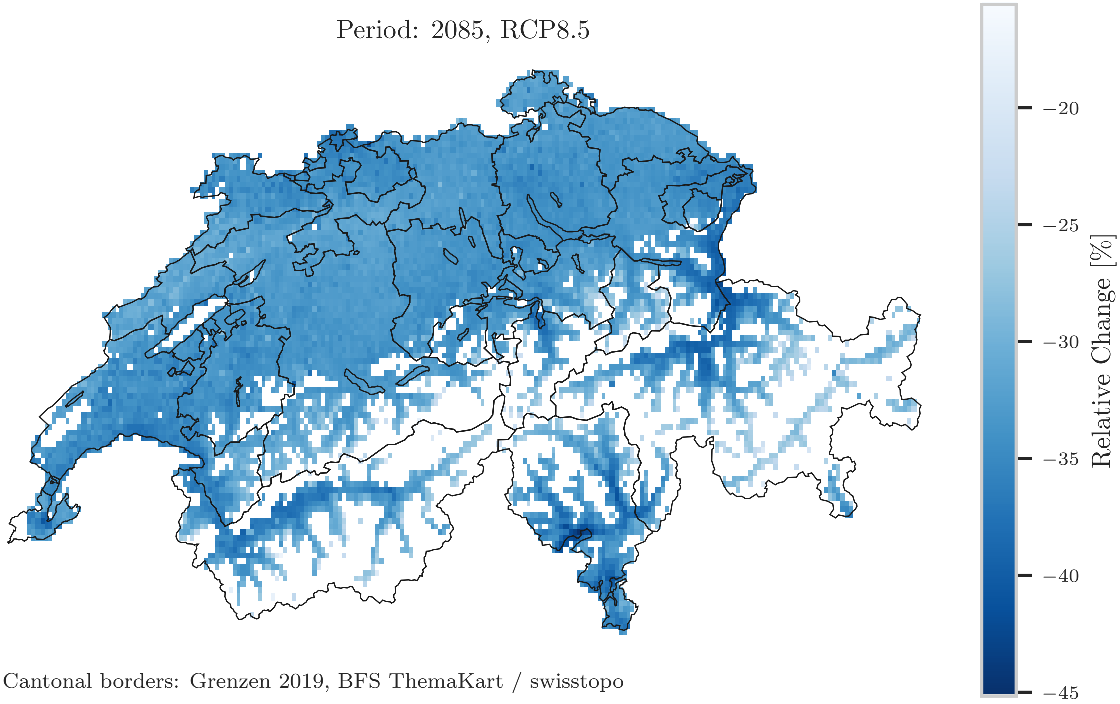

Figure 4. Spatial distribution of relative change of space heat demand for period 2085 and RCP8.5 compared to the reference period.

assessment (for heat demand and especially cooling demand), it is necessary to evaluate energy demand using dynamic calculations that take into account heat storage effects inside the building mass. SIA 380/1 is a steady-state heat demand algorithm that is not able to account for such effects. Finally, due to the use of monthly aggregated temperature values, this study does not allow to identify the impact of extreme periods.

However, the results of this study hold valuable information for policymakers in order to prioritize and plan effective and targeted environmental refurbishment strategies of building stocks that are tailored to specific regions. Furthermore, the findings can also support energy providers such as operators of district heating networks to streamline their future plans with the anticipated change in heat demand.

6. Conclusion

Linking the existing building stock model with the CH2018 climate change scenarios allowed us to identify the spatio-temporal impact of different climate change projections on the energy demand of today's building stock. By modeling the energy demand for space heating until the end of this century, regional differences are identified. In general, the overall trend suggests a nationwide decrease in space heating demand, which in turn also leads to a reduction in greenhouse gas emissions. Nonetheless, the temperature increase may make space cooling necessary in the future to ensure comfortable indoor conditions.

Acknowledgments

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