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IMPACT OF CLIMATE CHANGE TO THE TOTAL AND PEAK ENERGY DEMANDS OF A NORTHERN FINNISH BUILDING BY 2050

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ABSTRACT

Due to climate change, global average outdoor temperatures are expected to further increase, modifying the energy demand of the buildings from today. As new buildings are constructed to last, the impact of climate change should be taken into account during the design phase. The objective of this study is to investigate the changes in total and peak energy demands in buildings having different levels of thermal insulation, to explore if the impacts of climate change are similar to all selected building types by 2050. The impact of climate change to the weather data is gathered from different climate change projections to achieve a comprehensive analysis of the possible future directions. The new weather files are created using 'morphing' method and using meteorological test reference year for building simulation and measured weather data for constructing the future weather files. The results indicate that the energy demand will decrease by 6-12% in passive building types by 2050, with heating demand decreasing 6-13% and by starting to have cooling demand in A1B, A2 and RCP8.5 scenarios for passive building. The scenarios with higher projections for temperature increase also have larger decreases in total energy demands indicating that the starting of having cooling demand does not overcome the decrease in heating demand. Moreover, the peak demand for heating is projected to decrease in the future but, at the same time, peak cooling demand starts to occur, which may need to be considered in the future energy system constraints.

Keywords: climate change, energy demand, heating demand, cooling demand, peak capacity, North Finland

1. INTRODUCTION

Climate change has been acknowledged as one of the grand challenges and its impacts are rising average global temperatures and changes to the climate and weather as it is known today. As buildings are built to last long, even over 50 years, the decisions made today on the building stock will impact the future energy use of buildings. Therefore, the impact of climate change on the energy efficiency on the buildings should take into account the impact of climate change, in order to prevent decisions that may impair the energy efficiency of buildings in the future. Currently, Finland is a heating dominated country where 83 % of the total energy consumed in residential buildings was used in heating in 2017 [1]. The change of the energy demand in the future is studied by Jylhä et al. [2] who found that climate change is expected to decrease the heating demand of spaces and ventilation of residential buildings in South Finland by 20-40 % by the year 2100. The total energy demand was found to decrease by 20-35% by the same time, even though the cooling demand increases 40-80%. By 2050, the heating demand was found to decrease by 15-18%, cooling increase 28-34% and total energy demand decrease by 13-17%. Hence, the study did not find that the increase in cooling demand would result in increase of total energy demand. Yet, these results were achieved with the old climate change projection scenarios and mainly studied the impact in the South of Finland. Furthermore, it does not assess different building types or the impact to peak energy demand, creating the need to analyze these parameters as well.

The climate change projections for the future are simulated with different climate models, of which results are ensembled from Coupled Model Intercomparison Project Phase 5 (CMIP5) models for Representative

Concentration Pathways (RCP) scenarios (RCP 2.5, RCP 4.5, RCP 6.0 and RCP 8.5) and CMIP3 models for Special Report on Emission Scenarios (SRES) (B1, A1B and A2) to present various greenhouse gas (GHG) scenarios to assess the change in climate accordingly. The temperature changes in Finland are estimated to be 2-6°C in the SRES [3] and 2-7°C in RCP scenarios [4] with both of the results showing higher increase of temperatures during the winter than summer.

The objective of the work is to study the impact of climate change on total and peak energy demands of a detached house in North Finland. The aim is to investigate the increasing temperatures and whether this will increase or decrease the energy demand through increased cooling and decreased heating needs. Furthermore, the study assesses the changes in peak energy demands, as they influence the design of the energy system through the need of generation capacity to meet the peak demands. The impact of the building types is also examined to see if improved thermal insulation affects the results compared to less insulated buildings. The influence of climate change is simulated using an existing thermal model [5] which is modified to utilize ISO 52016-1 standard to calculate the energy demand and indoor temperature of the building. The climate change projections on the monthly temperature changes are gathered from available databases and future weather files are created based on them.

2. MATERIALS AND METHODS

2.1 Thermal model

This research is based on thermal [5] and smart house [6] models developed earlier, which both are utilized to test out the energy demand change due to climate change by 2050. The energy demand calculations are slightly different from presented thermal model as the energy demand calculations have been modified to comply with the hourly calculation method from ISO 52016-1 with the heating temperature limit of 21°C and cooling temperature limit of 27°C as set in the Finnish regulation [7]. Additionally, the energy demand calculations use the constant temperature setting for heating scenario from the thermal model and add heat demand for ventilation as calculated in EN 16798-5-1 and [5] to the total energy demand. For cooling, the passive cooling impact from the demand-controlled ventilation is calculated and added to the cooling demand if applicable.

2.2 House types and location

The simulation uses three different types of residential buildings, which all have different levels of energy efficiency and thermal insulation. The first two building types are taken from Finland's national regulations on the energy efficiency of the building from 1985 [8] and 2018 [7]. The third building type is considered a possible future building type with the thermal insulation level equal to passive house, which is assumed to have a total heating and cooling energy demand of 25 kWh/m^2/a in current Jyväskylä environment [9]. The dimensions of the building, the selected appliances for the use and other input values for the existing smart house model are the same as in [5].

Weather data used in the simulations is divided to test reference years (TRY), actual measured weather data and to future climate projections. The simulation is conducted in a Northern Finnish environment by selecting Oulu as a suitable location. Jylhä et al. [10] created TRYs for building simulations for today's climate, and for future climates under the A2 scenario in [2,11]. As Oulu is in the area III of the created geographical areas, its TRY2012 was selected to a current reference scenario. The other reference scenario is selected from a timeframe between of 2012 and 2015 to present different existing years. The temperature data were gathered from Vihreäsaari, Oulu, measuring station and the global irradiance from Kuolaniemi, Sotkamo, which is the closest global irradiance measuring station to Oulu and, which both have data available from [12]. The datasets were validated, negative global irradiance values were removed and the missing datapoints were interpolated from the existing datapoints from the boundaries of the missing datapoints. In case there were datapoints missing from several hours, the missing datapoints were taken from the previous day's datapoints from the same hour.

The future datasets to 2050 are created from various climate change projections to create a sufficient representation of the possible future pathways. The future weather files were created utilizing 'morphing' technique [13] in which the current weather data is modified to represent the future weather by the changes in absolute and relative values by the climate change. A technique to create the future weather files from the monthly change in the mean values and the change in the monthly variance [2,14,15] is also applied in this study. The absolute changes in monthly mean temperatures in Oulu were gathered and interpolated from the provided values from [16] for B1, A1B and A2 scenarios for 2050, so that the new average temperature is equal to the values from the climate change database, and the TRY2012 is used as a reference. The solar irradiance for these scenarios was taken from the TRY2050 for area III [2]. Furthermore, 2 RCP scenarios (RCP4.5 and RCP8.5) were also utilized to create future weather files by climate change projections. The changes in the long-term monthly mean temperatures for the RCP scenarios were gathered from [17] by selecting ensembled mean from their regional climate models. The values were taken from the whole of Finland, as its average values were closer to the measured average value from Oulu in 2012-2015 than the changes in the cluster options. The mean temperature change was calculated to make the average temperature of the created future weather file to match the projection. Additionally, the change in global irradiance by month was gathered from the same source. The change in variance of temperature by every three months were gathered from [4]. The RCP scenarios were also used to create a future weather file by the measured values from 2012 to 2015 to test what the occurred weather would be like in 2050.

3. RESULTS AND DISCUSSION

The results of the simulations are presented in Figures 1 and 2, of which Figure 1 presents the impact of climate change to the building's annual energy demand, and more specifically on heating and cooling demands, and the latter presents the change of peak heating and cooling energy needed. As Figure 1 indicates, the energy demand in all the buildings decreases as the result of climate change by 2050. The results would indicate that the energy demand decreases more (~-8-12%) with scenarios having higher mean temperature increase (A1B, A2 and RCP8.5) than in scenarios with less increase in the mean temperature (~-4-7% for B1 and RCP4.5). The heat demand decreases 3.8-13.1% in all the scenarios. There is no cooling demand in the TRY2012 scenario in any building types, whereas in the future scenarios passive building starts to have cooling demand in A1B, A2 and RCP8.5 scenarios (4-107 kWh/a). Yet, as the total energy demand still decreases in all the scenarios, the cooling demand does not overcome the decrease in heating demand. Moreover, the buildings with lower level of thermal insulation (1985 building), have also lower decrease in energy demand than passive building type with more insulation (-4-10% and -6-12%, respectively). Comparing the scenarios from the actual measured weather data, the impact of climate change is much smaller compared to the TRYs, and the energy demand of passive building even stays the in the same level in RCP4.5 scenario compared to today. Conversely, in the same scenario the cooling demand would decrease by 15% from today whereas the heating need increases by 0.1%. The RCP8.5 scenario then has 5.9 and 6.2% less total and heating energy demand, respectively, whereas cooling demand increases 30 and 13% in 2018 and passive buildings, respectively, and even 1985 building has cooling demand (1.3 kWh/a). Generally, these results show slightly less decrease in heat demand than what was found on [2], but shows similar trends in decreasing energy and specifically heating demand, and need of cooling.

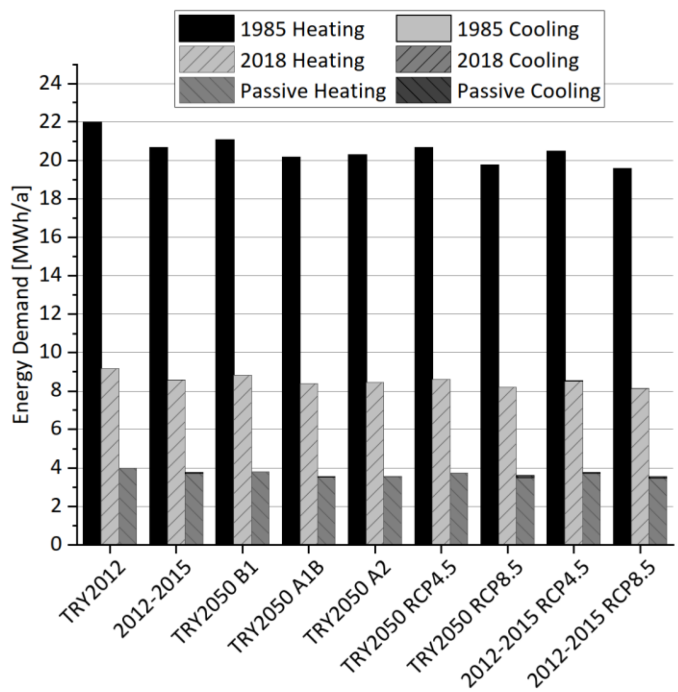

Fig 1 Annual energy demand of buildings stacked for heating and cooling in different climate change scenarios.

The peak heating and cooling capacities give implications on the needed peak capacity of the energy system as it must be designed to have enough generation capacity to keep the power system balanced. The results on Figure 2 indicate that, during the winter time, the maximum heating capacity in a building decreases by 2.2-10.3%, but relatively less than the total energy demand. This would indicate that there needs to be capacity to meet the peak power need, but it might be operated less than today, as the energy demand decreases. Conversely, there is no capacity requirements on cooling by the results nowadays, but in the future cooling requirements will start to exist, and even though the cooling energy demand may be small, the capacity

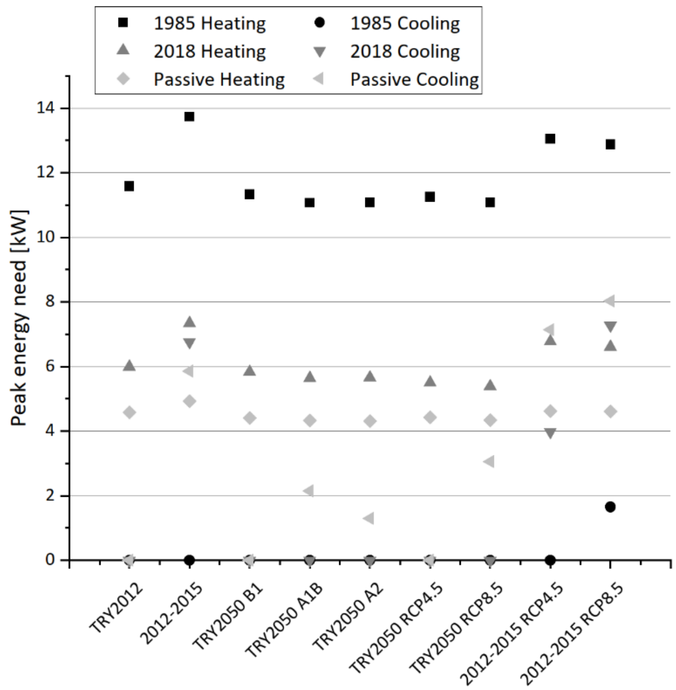

Fig 2 Peak energy needs for heating and cooling in different climate change scenarios.

requirement can be as large or even larger than the heating peak capacity. This results in a possible change in the design of the energy system as it may also need peak capacity for small annual generation, but high peak capacity during the summer, which does not exist with TRY2012 simulations.

4. CONCLUSIONS

Due to climate change and increasing average outdoor temperature, the energy demands of buildings will change radically in the North of Finland. All regions categorized as cold-climate regions in 2012 will likely to face an increased demand for cooling, especially for newer building complying to the passive house standards. However, the energy demand in all the building types is projected to decrease by 4-12% by 2050 with heat demand decreasing 3.8-13.1% in the TRY scenarios. Currently there is no cooling demand in any building types, but in the A1B, A2 and RCP8.5 scenarios, the passive building starts to have cooling demand of 4-107 kWh/a in TRY based scenarios. The energy demand decreases less with the least insulated buildings (-4-10%) compared to passive buildings (-5.5-11.8%). Furthermore, the energy demand reduces more in scenarios having higher temperature increase projections for 2050 (~-8-12% in A1B and ~-10-11% in RCP8.5) than in scenarios with lower temperature increase projections (~-4-6% in B1 and ~-6-7% in RCP4.5). The peak energy demand for heating is projected to decrease ~2-10%, while there starts to be peak cooling demand of 1-3 kW in the A1B, A2 and RCP8.5 scenarios for passive building. The peak energy demands are higher in the scenarios based on measured data, showing the need of having peak capacity to match the heating and cooling peaks in the future.

This research was carried out considering an optimally oriented building and therefore more extreme cases may arise when buildings are oriented towards West in high latitudes. Future research will integrate buildings with other energy networks that will shape future cities and their integration of climate change in their infrastructures.

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