Optimising Weather Data Reference Periods for Building Simulation Climate Data in a Changing Climate

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Background

In 2015, the global average temperature exceeded the 1961–1990 average by approximately 0.76 ± 0.09°C (World Meteorological Organisation, 2016). Moreover, the years spanning from 2015 to 2022 have marked the eight warmest years on record, and it is expected that this trend of increased warming will persist due to rising anthropogenic greenhouse gas emissions. These developments have significant implications for the relevance and quality of climate data employed for building simulations.

Climate files used in building and renewable energy system simulations typically consist of 8,760 hourly records of meteorological elements which are derived from historical data to represent long-term climatic conditions (Cui et al., 2017). Within the context of a warming climate, conventional reference periods for which the weather data are derived—such as the Commonwealth Scientific and Industrial Research Organisation's (CSIRO) reference period of 1990-2015—might no longer accurately represent the current or projected short-term future climate at a given location.

The climate data commonly used by modellers for demonstrating compliance with energy efficiency provisions in the National Construction Code (NCC), sizing HVAC systems and optimising building designs is likely not an accurate representation of the climate that the building will experience during its operating life.

Purpose

In this paper, we propose the adoption of shorter, more recent reference periods that better characterise evolving climate dynamics and have the potential to improve the quality and suitability of building simulations, especially with regards to energy modelling. We implement a 15-year reference period spanning from 2008-2022, comparing this to a 33-year reference period from 1990-2022 as well as the CSIRO reference period of 1990-2015. The 15-year reference period is expected to offer a more accurate reflection of the ongoing effects of global warming, making it suitable for assessing both short-term and long-term trends in building performance and energy demand.

Method

Historical weather data provided by the Bureau of Meteorology (BOM) from 1990 to 2022 for Sydney was processed through our in-house software "ClimateCypher" to produce 33-year weather data in a format suitable for conducting simulations through EnergyPlus. We then applied this data to three archetype models of NCC compliant buildings: a supermarket, 3-storey office and 10-storey office.

Trends in the annual and monthly energy use and heating and cooling demands were analysed for each building individually, and for the buildings as a collective, to assess how they have evolved over the years, specifically in relation to the aforementioned reference periods. A temporal analysis considering dry bulb temperature, dew point temperature, relative humidity, wind speed, global horizontal irradiation (GHI), and direct normal irradiation (DNI) was also performed, as these meteorological elements have a significant impact on building energy modelling.

Results

The results showed a significant decrease in heating demand from 1990-2022 for each building archetype individually and for when their collective results were examined. There was also a clear trend of rising annual average cooling demand and total heating, ventilation, and air conditioning (HVAC) energy usage over this time period (Figure 1). Notably, the cooling demand from 2015 to 2019 was relatively high, suggesting the importance of including weather data from this period into building simulations to more accurately address the impact of climate change on building energy consumption. Additionally, it is worth mentioning that a decrease in cooling demand was observed since 2019, reflecting an 8.79% reduction from 2019-2022, despite the overall positive trend. This shift may be attributed to various factors, including temporary fluctuations in local weather conditions, and we intend to revise this work in future years to evaluate whether it is a short-term blip or a part of the longer-term trend.

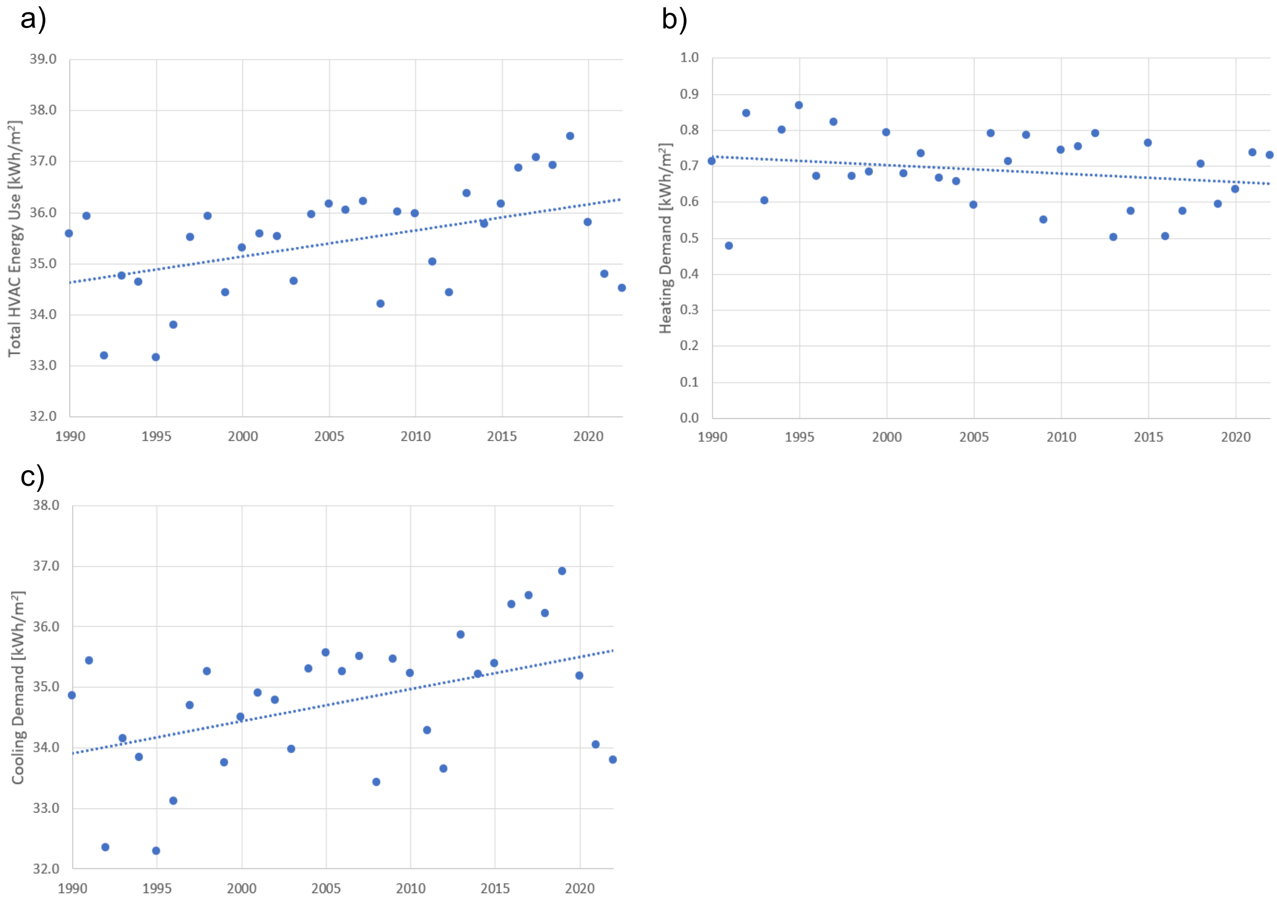

Figure 1. Average annual (January - December) (a) total HVAC energy consumption, (b) heating consumption, and (c) cooling consumption, from 1990-2022 for Sydney for all three NCC-compliant building archetypes.

On a monthly basis, the simulation results consistently demonstrated that for the 10-storey office building archetype, total HVAC energy consumption was at its minimum during the winter months and reached its peak during the summer months (Figure 2). This pattern is primarily driven by the increased cooling energy demand in summer and aligns with anticipated seasonal variations.

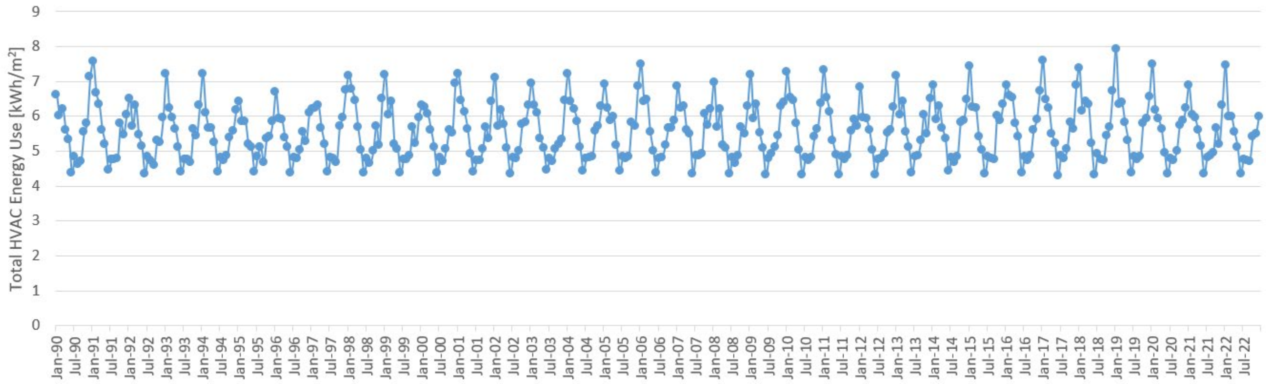

Figure 2. Time series plot for total HVAC energy consumption per month from 1990-2022 for Sydney for the 10-storey building archetype.

While the monthly heating and cooling consumptions exhibited a relatively consistent seasonal pattern, variations in the maximum heating and cooling energy demands were observed, particularly from 2015 onwards. A trend of lower maximum monthly heating demand, occurring in the winter months from 2016 to 2022, was discernible when compared to the entire 1990-2022 period (Figure 3). Similarly, there was a trend of higher maximum monthly cooling demand, occurring in the summer months between 2008 and 2022, with a notable increase beginning in 2015 (Figure 4). These findings are indicative of a warming climate.

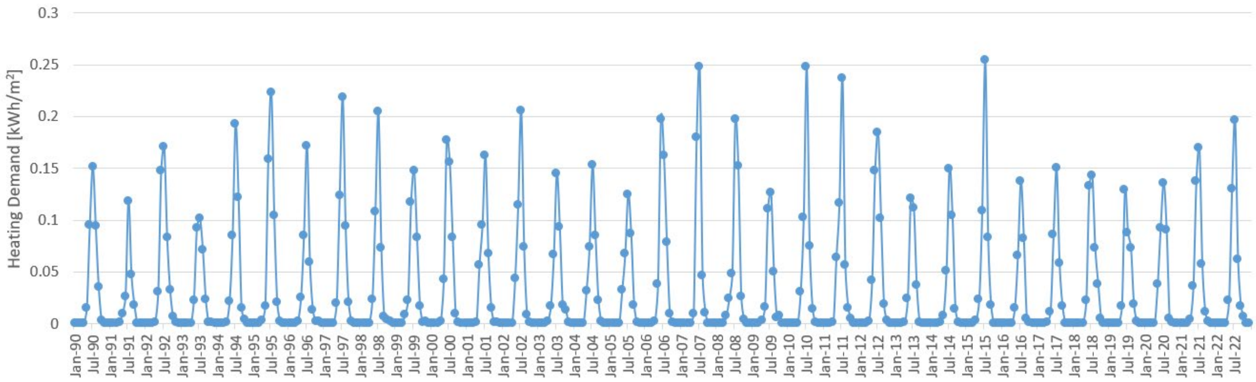

Figure 3. Time series plot for heating demand per month from 1990-2022 for Sydney for the 10-storey building archetype.

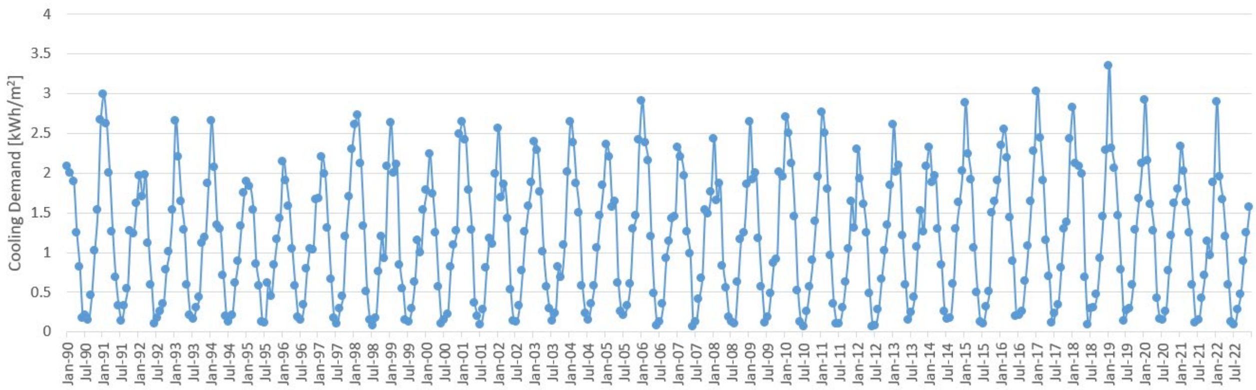

Figure 4. Time series plot for cooling demand per month from 1990-2022 for Sydney for the 10-storey building archetype.

A temporal analysis was conducted by calculating the monthly averages of selected meteorological elements over time periods of 1990-2022, 1990-2015, and 2008-2022. Comparing the monthly averages of 1990-2015 with 2008-2022 showed a rise in mean dry bulb temperature, dew point temperature, relative humidity, and wind speed of 0.24°C, 0.38°C, 0.81 percentage points, and 6.64%, respectively; and a decrease in GHI and DNI of 2.40% and 7.36%, respectively. Likewise, comparing the monthly averages of 1990-2022 with 2008-2022 showed a rise in mean dry bulb temperature, dew point temperature, relative humidity, and wind speed of 0.18°C, 0.24°C, 0.38 percentage points, and 5.77%, respectively; and a decrease in GHI and DNI by 1.92% and 5.78%, respectively. The monthly averages for the periods 1990-2022 and 1990-2015 were comparable, although the GHI and DNI were higher each month in the 1990-2015 period, and slightly lower for all other meteorological elements.

Discussion and Conclusions

These findings collectively suggest substantial shifts in the local climate over the 2008-2022 reference period. It is therefore reasonable to expect that more frequent updates and shorter measurement periods will yield greater predictive accuracy for meteorological conditions, and by extension, building simulations (Trewin, 2007).

The analysis of reference periods from 1990-2022, 1990-2015, and 2008-2022 suggests that traditional reference periods, such as CSIRO's 1990-2015 period, may fail to adequately represent the changing climate. This is evident from the shifts observed in cooling demand and the trends in critical meteorological elements used in building simulations within the 2008-2022 period. Henceforth, it is important to consider more recent and dynamically evolving reference periods to enhance the accuracy and relevance of weather data for building simulations.

Further analysis considering different climate zones than that of Sydney (NCC CZ5), is under-way. Additionally, further investigation of the annual variations and timing of peak cooling loads would be valuable, as peak cooling loads are important in building optimisation through simulations as they influence the sizing and costs of HVAC systems, budgeted energy consumption, and indoor comfort levels. Understanding how these peak loads vary with climate change will inform more efficient and resilient building designs and systems.

References

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