Enhancing Australia's Weather and Climate Data for Energy System and Weather-proofing Simulations

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Background

In 2023 the global average temperature exceeded the 1961–1990 average by approximately 0.98°C (Australian Government Bureau of Meteorology, 2023) marking 2023 as the warmest year on record. This trend has continued due to rising anthropogenic greenhouse gas emissions, significantly impacting the relevance and accuracy of climate data used in renewable energy system and building energy and weather-proofing simulations.

Climate files used typically consist of 8,760 hourly records (one year) of meteorological elements derived from historical data to represent long-term climatic conditions (Cui et al., 2017). However, with ongoing climate warming, conventional reference periods such as the Commonwealth Scientific and Industrial Research Organisation's (CSIRO) 1990-2015 reference period no longer accurately reflect the current or projected short-term future climates at specific locations.

The climate data commonly used by modelers to demonstrate compliance with energy efficiency provisions in the National Construction Code (NCC), to size HVAC systems and to optimise building and energy system designs does not accurately represent the climate conditions that such systems will experience during their operating life.

Furthermore, CSIRO 1990-2015 reference period doesn't include precipitation data, an important variable for building energy and weather-proofness simulations. The Fraunhofer Institute is developing its updated weather-proofing simulation software WUFI and, at their request in liaison with the University of Tasmania, we are contributing to it by supplying typical meteorological year data, including precipitation, based on the most recent 15 years for 68 NatHERS climate zones. This data will be used to simulate weather-proofness and condensation hazard (leading to mould and its corollary health hazard) addressed by the Condensation provisions in the NCC.

Purpose

This abstract updates our work in this field (Patterson et al, 2023) and proposes adopting shorter, more recent reference periods that better capture evolving climate dynamics and improve the quality and suitability of building and system simulations, particularly for energy modeling.

We implement the latest 15-year reference period from 2009-2023, comparing this to a 34-year reference period from 1990-2023 as well as the CSIRO reference period of 1990-2015. These CSIRO files were known for two-and-a-half years to have multiple timing errors skewing the simulation results but these have belatedly been corrected (CSIRO, 2024). The authors used corrected versions generated in house for this study and have criticised the apparent deceit of the 'update' issued in August 2024 (Lee, 2024). The 'update' gives no guidance as to the severity of the skewing and hence of the necessity to repeat a wide selection of simulations done with the errant data as a sensitivity analysis.

The 15-year reference period is expected to more accurately reflect the ongoing effects of global warming, making it suitable for assessing both short-term and long-term trends in building performance and energy demand. They have the added advantage of allowing their supplementation with precipitation data (mostly rainfall) without the need for any synthesis of hourly data by the disaggregation of daily data (Arora et al, 2024). This advantage was also cited in submissions to the NCC 2025 review committee.

In addition, monthly updates of the most recent data can be used for resilience testing and operational optimisation of buildings including commissioning. This function is supported by the monthly publication of a Weather and Energy Index for three archetypical buildings and one domestic solar PV system in all eight capital cities (Exemplary Energy, ongoing) as well as providing the trailing-12-months datasets for refined commissioning and analysis of finished projects in operation.

Method

Historical weather data provided by the Bureau of Meteorology (BOM) from 1990 to 2023 for 230 Australian locations including our 8 Capital cities and our 61 other NatHERS Climate Zones (CZs) were processed using our in-house software “ClimateCypher” to produce 34 years of weather data in NatHERS format and EPW format suitable for simulations through EnergyPlus and most commercially available simulation packages. To analyse climate trends in our capital cities, this data was then applied to three archetype models of NCC-compliant buildings: a 1-storey supermarket building, a 3-storey office building and a 10-storey office building.

Trends in annual and monthly energy use and heating and cooling demands were analysed for each building archetype individually and collectively to assess how these have evolved over the years, particularly concerning the aforementioned reference periods. A temporal analysis considering dry bulb temperature, dew point temperature, moisture content, wind speed, global horizontal irradiation (GHI), and direct normal irradiation (DNI) was also performed, as these meteorological elements significantly impact renewable and building energy modelling results.

Results

The results indicate consistent trends in heating and cooling energy consumption across all eight capital cities from 1990 to 2023 (Figure1 and 2). Based on NCC Climate Zones, warmer regions such as Adelaide (CZ5), Brisbane (CZ2), Perth (CZ5) and Sydney (CZ5) have more pronounced trend changes, with a 13.9% increase in cooling energy consumption from 1990 to 2023.

In contrast, while all cities have downward trends on heating energy consumption, only Hobart (CZ5) has a significant decline (24.4%) from 1990 to 2023 and the other cities (without Darwin) have very slow decreases over the same period.

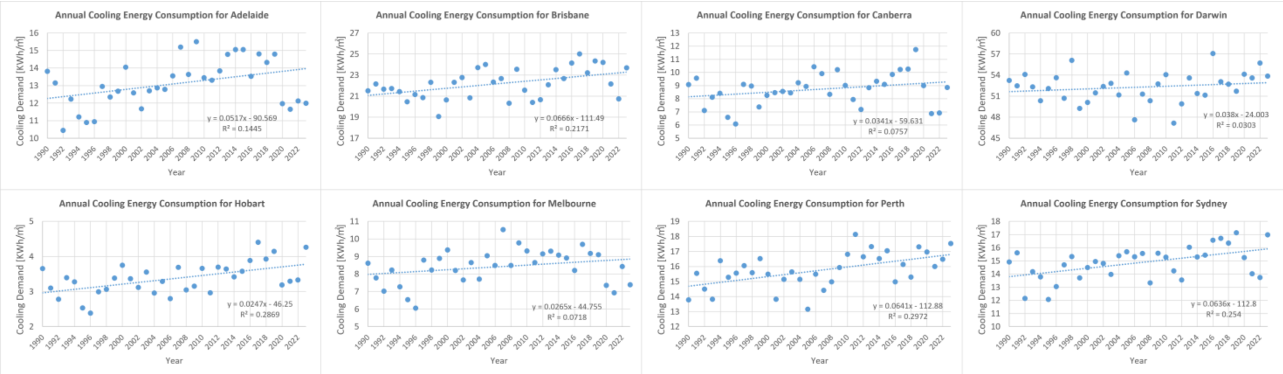

Figure 1. Annual cooling energy 1990-2023 for 3 NCC-compliant building archetypes.

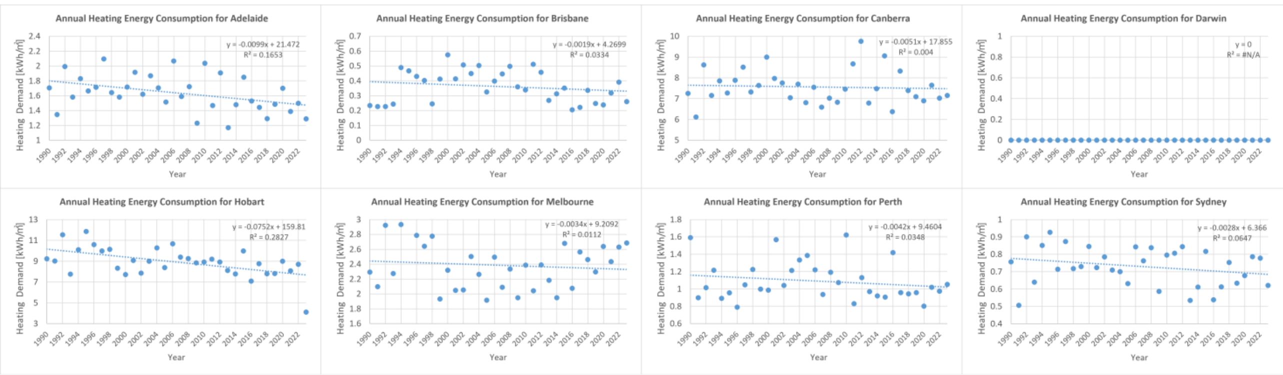

Figure 2. Annual heating energy 1990-2023 for 3 NCC-compliant building archetypes.

For heating and cooling energy consumption, we compared three periods: 1990-2004, 1990-2015 and 2009-2023, using typical meteorological years representing those eras. As shown in Figure 3, the heating energy consumption simulations for Sydney from 1990 to 2015 are similar to or slightly higher than those from 1990 to 2004. However, during the 2009-2023 period, heating energy consumption is lower from April to October. Differences range from 63.24 Wh/m^2 in May for 10-storey offices to 0.25 Wh/m^2 in April for 3-storey offices.

In contrast, the cooling energy consumption simulations for 2009–2023 reveal higher demand across all archetypes compared to the 1990–2015 period, except in February for all archetypes and October for supermarkets. When compared to the 1990–2004 period, only February, April, and December show lower cooling energy consumption for all archetypes, with June exhibiting a decrease for 3-storey and 10-storey offices. Overall, the average cooling consumption for the three archetypes during 2009–2023 is 9.46% higher than for 1990–2015 and 0.8% higher than for 1990–2004.

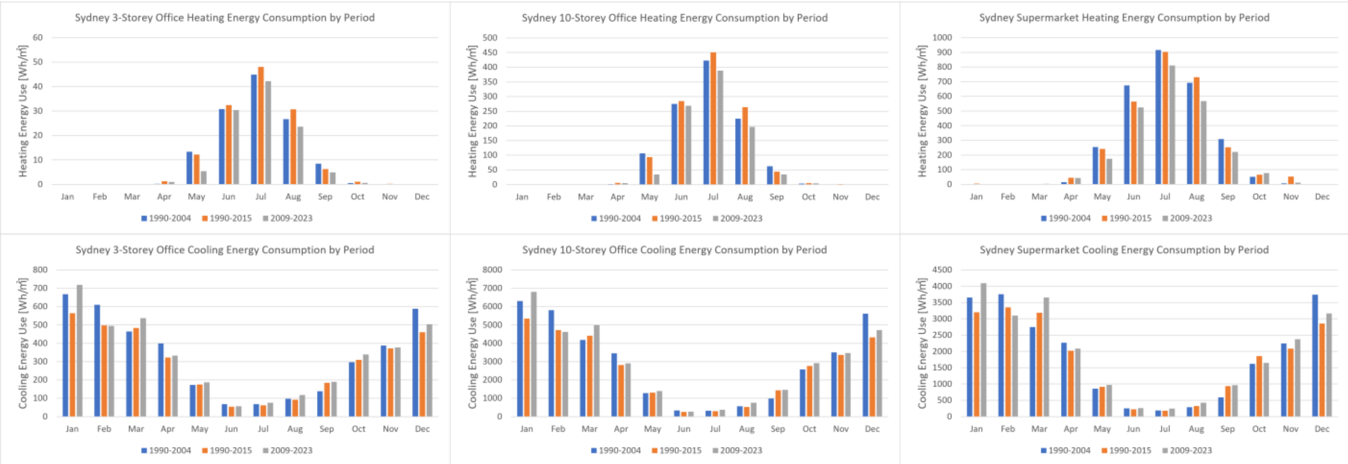

Figure 3. Monthly simulation results for the three contending typical meteorological years in Sydney.

Regarding weather trend changes, a comparison of monthly averages from 1990–2015 and 2009–2023 reveals increase in average mean dry bulb temperature, moisture content, and notably, there are significant differences in precipitation between 1990–2015 and 2009–2023 across Australia. Brisbane, Canberra, and Sydney experienced increases in average precipitation of over 15 mm, specifically 15.46 mm (20.3%), 20.86 mm (62.93%), and 25.28 mm (31.42%), respectively, in the 2009–2023 period.

Table 1 highlights the changes in energy consumption patterns across Australia's capital cities from 1990-2015 to 2009-2023. In 2009-2023 period, all cities saw an increase in cooling energy consumption and a decrease in heating energy usage, which corresponds with rising average dry bulb temperatures, moisture content, and precipitation levels.

This trend underscores the significant impact of climate change, as warmer moister weather results in a reduced need for heating and a heightened demand for cooling solutions. These findings reinforce the idea that, as Australia continues to experience rising temperatures and shifting weather patterns, cooling energy consumption will continue to increase.

Table 1. Average Weather and Energy Trend Comparison: 1990-2015 and 2009-2023

Average	Dry bulb Temperature (℃)		Moisture Content (g/kg)		Precipitation (mm)		Heating Energy Consumption (Wh/㎡)		Cooling Energy Consumption (Wh/㎡)	
	1990-2015	2009-2023	1990-2015	2009-2023	1990-2015	2009-2023	1990-2015	2009-2023	1990-2015	2009-2023
Adelaide	17.03	17.3	6.88	6.93	41.13	44.37	1.692	1.517	13.105	13.745
Brisbane	20.17	20.56	10.69	11.03	76.15	91.61	0.388	0.161	21.782	28.931
Canberra	13.31	13.37	6.78	6.99	33.15	54.01	7.657	7.595	8.561	9.024
Darwin	27.28	27.48	15.87	16.32	152.65	149.23	N/A	N/A	51.757	52.784
Hobart	12.73	13.03	6.08	6.17	49.72	49.02	9.303	8.204	3.241	3.638
Melbourne	15.76	15.78	7.12	7.4	44.73	50.4	2.360	2.357	8.453	8.699
Perth	18.46	18.69	7.82	7.74	60.32	54.54	1.114	1.039	15.568	16.609
Sydney	18.16	18.4	9.07	9.39	80.45	105.73	0.748	0.693	14.555	15.479

Conclusions

These findings collectively suggest substantial shifts in the local climate over the 1990-2023 reference period. Consequently, more frequent updates and shorter measurement periods may yield greater predictive accuracy for meteorological conditions, and by extension, renewable and building energy simulations (Trewin, 2007).

The analysis of heating and cooling reference periods comparisons from 1990-2004, 1990-2015, and 2009-2023 suggests that traditional reference periods, such as CSIRO's 1990-2015 period, do not adequately represent the current situation in a changing climate. This is evident from the shifts observed in cooling demand and the trends in critical meteorological elements used in building simulations. Therefore, it is crucial to consider more recent and dynamically evolving reference periods to enhance the accuracy and relevance of weather data for renewable and building energy and weather-proofing simulations.

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