

Building for the Future

Evaluating a new approach to developing average and extreme future weather files for residential building simulation in Australia.



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Executive Summary

Residential buildings constructed today are expected to remain in use well into the 2070s. By that time the climate in Australia is projected to be significantly warmer than the historical baseline used by building designers in thermal performance assessments. This disconnect creates a growing risk that homes designed for past conditions could experience increased cooling loads, overheating, reduced comfort and potentially increased health risks for occupants.

Bringing together climate scientists and building simulation expertise in the Climate Systems Hub, using high resolution regional climate projections derived from seven Global Climate Models (GCMs), we generated both future Typical Meteorological Year (TMY) files for building energy performance simulation and eXtreme Meteorological Year (XMY) files designed to represent distinct heatwave characteristics.

Prototype files were developed for eleven representative Australian locations across cooling-dominated, balanced and heating-dominated climates. They cover an upper and lower emissions pathways, SSP1-2.6 and SSP3-7.0, and three future periods centred on the 2030s, 2050s and 2070s. The files were formatted for compatibility with Nationwide House Energy Rating Scheme (NatHERS) accredited building simulation software and tested by building designers and NatHERS assessors using tools including HERO, FirstRate5 and AccuRate. Testing confirmed that while the prototype TMY and XMY files are technically fit-for-purpose: they contain the required variables, can be used in existing residential simulation workflows. However, the additional climate information and range of available files create new interpretation and implementation challenges for practitioners. The simulation results show a clear warming trend across Australia with variations across the regions. Future TMY files show currently cooling-dominated locations such as Darwin, Cairns, Brisbane and Longreach show large increases in cooling demand, while currently balanced climates such as Sydney, Perth, Adelaide and Mildura shift towards greater cooling and reduced heating. In southern heating-dominated locations such as Melbourne, Canberra and Hobart, reduced heating demand seems to offset increasing cooling demand under typical conditions, although this does not remove the need to assess performance and potential risks to occupant health during future heatwaves.

The extreme (XMY) files provide an important new capability (currently not possible using current NatHERS files) by XMY files allow practitioners to explore the potential to assess future heatwave performance, including thermal comfort, peak cooling demand and potential occupant health implications. Results show increases in heatwave frequency, intensity, duration and severity across representative locations, although like the TMY files the estimated building performance outcomes varied substantially across not only emissions pathways but also between climate models. The differences in the projected weather conditions between climate models (under the same emissions scenario) translated into significantly different predicted heating and cooling loads. Cooling loads for Sydney varied by up to 259% between models (under the same emissions scenario). Design responses that would achieve compliance could therefore vary widely depending on the choice of climate model, which introduces a risk of inappropriate outcomes when trying to improve future resilience.

Executive Summary

The future weather files developed through this project could substantially improve the ability to design homes for future climate conditions, but their widespread application will require clear guidance on the selection and interpretation of emissions scenarios, climate models, time periods and file types. The range of possible future climates creates a major implementation challenge. More co-designed work is required to provide guidance on how results should be interpreted when different climate models produce different performance outcomes. A key limitation is that the prototype files developed are compatible for residential applications only; extending them to EnergyPlus (.epw) formats for commercial buildings will require robust methods for representing future precipitation. Including precipitation requires a new methodology, as future rainfall trends vary widely across climate projections. Extreme weather files add a new heatwave stress-testing capability, and as humidity is critical variable for thermal comfort and human health implications; more work is needed to accurately represent humidity in both observations and future climate projections. Urban heat island effects not included; applying the methodology to ~4 km projections could improve local climate representation, however this may still be limited by the underpinning observations.

We found that while the methodology provides a strong foundation for incorporating future climate conditions into residential building performance assessment, the technical file development alone is not sufficient. Appropriate application of this new information will require practical guidance, agreed use cases, further testing across dwelling types and climates, and an ongoing partnership between climate scientists, building simulation experts, policymakers and industry practitioners. Establishing a national capability to maintain, update and support the use of future weather files would help ensure that Australian buildings are designed for tomorrow's climate instead of yesterday's.



Introduction

Weather plays a central role in building design and operation, making the weather files used in building thermal performance simulation a critical input for assessing energy demand, thermal comfort, and overheating risk. In a warming climate, these interactions are becoming increasingly important, as higher average temperatures and more frequent extreme heat events place growing stress on buildings and energy systems. Internationally, some jurisdictions are recognising the need to incorporate future climate considerations in their building codes, for example, New York City, England and British Columbia in Canada (Gaur and Lacasse 2022; Hinge, 2023).

Heatwaves are among the most significant climate risks for buildings, affecting thermal comfort, occupant health, and electricity system reliability. This causes design challenges for building designers (Hinge, 2023). Australia has already experienced a marked increase in the frequency and intensity of extreme heat events in recent decades (CSIRO and BoM, 2024), and climate projections for Australia consistently suggest that this will continue, with increases in the frequency, duration, and intensity of heatwaves (Perkins et al. 2012, Cowan et al. 2014, Gergis et al. 2020, Trancoso et al. 2020).

Despite this, most building energy assessments in Australia continue to rely on weather files derived from historical climate observations (Upadhyay et al. 2022), increasing the risk of heat-related illness, thermal discomfort, and even mortality for building occupants (Hanna, et al., 2020). For new buildings, it is common to use building performance simulation to demonstrate compliance with the energy efficiency provisions within the National Construction Code (NCC). Around 90% of new homes are assessed using the Nationwide House Energy Rating Scheme (NatHERS) to demonstrate that they meet the NCC requirements. To satisfy modelling requirements in the code, climate files that are representative of a typical year for the proposed location are generally employed. NatHERS employ the Typical Meteorological Year methodology in their reference Meteorological Year (RMY) format; The current NatHERS weather files are derived from the 1990-2015 historical observations, and are intended to represent “typical” climate conditions rather than future average or extreme conditions (Liley, 2017; Ren et al. 2020). Commercial building simulations also typically employ a similar TMY methodology, however they have a different file format, that introduces small but significant methodology differences.

TMYs are constructed by selecting representative months from a multi-decadal historical record and combining them into a single synthetic year (Marion and Urban, 1995; Wilcox and Marion 2008). These files preserve realistic diurnal and seasonal variability at an hourly temporal resolution, while filtering out atypical years, making them suitable for standardised comparisons of annual building energy performance. However, by design, extreme heat and heatwave events are excluded from TMY files because TMY construction selects statistically representative months, substantial extreme events are unlikely to be selected and are not represented systematically. TMY files are therefore unsuitable for targeted assessment of heatwave performance, even though an individual selected month may still contain some hot conditions (Upadhyay et al. 2022, Machard et al. 2024, Ren et al. 2024, Yan et al. 2025).

Previous efforts to address the lack of weather files representing future climate conditions, both in Australia and internationally, have often relied on relatively simple adjustment techniques. These typically involve applying projected monthly mean climate changes to historical weather files, commonly referred to as “morphing” (Belcher et al. 2005, Ren et al. 2022, Machard et al. 2020, 2024).

In Australia, the morphing method has been used to develop future TMY weather files, including the CSIRO’s Projected weather files for building energy modelling (Ren et al., 2021, 2022) and Exemplary Energy’s ERSATZ future weather data files (Lee, 2018). As the morphing method applies projected monthly mean climate changes to historical weather files, these datasets represent changes in average future climate conditions only. Consequently, they tend to smooth day-to-day weather variability and underestimate changes in extremes (Molina et al. 2025). As a result, morphing-based weather files are poorly suited for assessing heatwaves, peak loads, and thermal stress under future extreme climate conditions.

Outside of Australia, methods have been developed to generate weather files for extreme or atypical conditions. For example, a Design Summer Year (DSY) represents a year with above average summer conditions (typically the third warmest summer over a 20-year period). DSY is primarily used in the UK for building performance simulations, particularly to assess overheating risks during hot weather and heatwaves (CIBSE, 2025). However, these approaches again rely on historical extreme events and do not account for how heatwaves themselves are projected to change under future climate scenarios.

Capturing these changes requires weather files that go beyond representations of average or ‘typical’ climate in the current NatHERS, and that explicitly characterise extreme heat events. To address this gap, the NESP Climate System Hub Building for the Future project developed a nationally consistent, co-designed methodology for generating future Typical Meteorological Years (TMYs) and eXtreme Meteorological Years (XMYs) for eleven Australian cities by applying climate change signals derived from dynamically downscaled regional projections to the established historical NatHERS dataset (Hoffmann et al 2026). The project produced a suite of prototype historical and future weather files for building performance simulation and then worked with building simulation practitioners to test the suitability of these files for use in residential building performance applications across Australian climate zones. The files were assessed to be fit-for-purpose based on the following criteria:

- compatibility with NatHERS-accredited software
- inclusion of required variables
- representation of plausible future average and extreme conditions
- interpretability for building performance applications
- practicality for industry use.

The remainder of the report is organised as follows. Section 2 presents the overall framework, datasets and methodology used to generate the future TMYs and XMYs. Section 3 explores the range of future climate conditions represented in the prototype files. Section 4

provides insights on how they translate into residential building energy performance, thermal comfort and resilience across Australian climate zones. Section 5 discusses considerations for future building policy, together with the study limitations and directions for future research. Finally, Section 6 summarises the main findings and conclusions.

2. Methodology

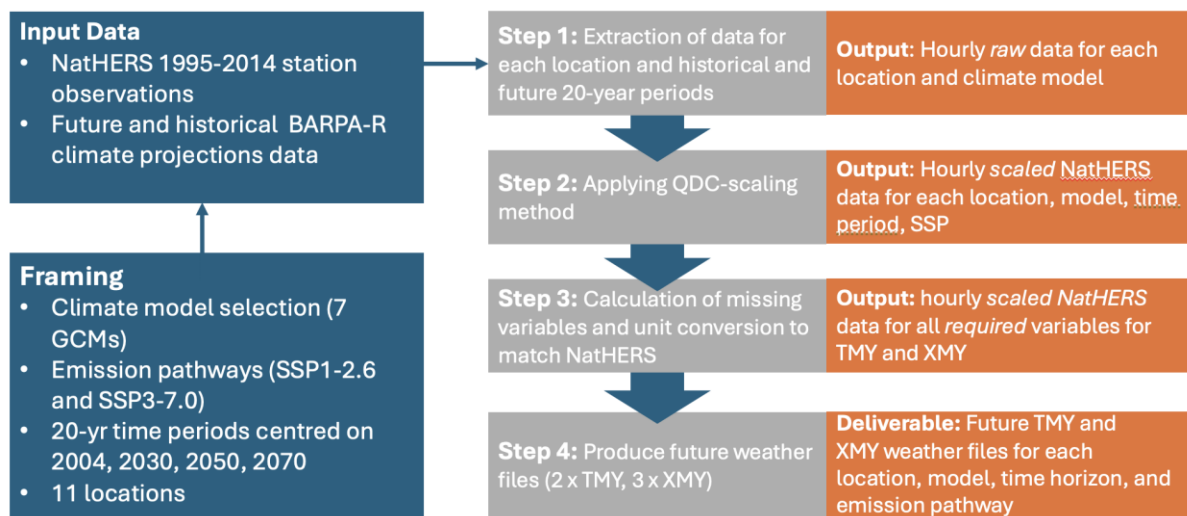


Figure 1: Methodology framework adopted in this study to generate typical (TMY) and extreme (XMY) meteorological year weather files

This study develops a dataset-agnostic methodology for generating future weather files suitable for building performance simulation (Figure 1). The methodology applies climate change signals derived from regional climate projections to the historical NatHERS data to produce simulation-ready future weather files. The resulting series retain the temporal sequencing of the historical data while incorporating projected changes in the distributions of selected meteorological variables. Although applied to Australian datasets and the NatHERS, the methodology is flexible and transferable to other observational datasets, climate model ensembles, geographical regions and building performance simulation tools and assessment frameworks.

The methodology is demonstrated for 11 NatHERS locations distributed across Australia, representing a range of cooling-dominated (Darwin, Cairns, Longreach, Brisbane), mixed climate (Perth, Sydney, Mildura, Adelaide), and heating-dominated (Hobart, Melbourne, Canberra) regimes relevant to residential building performance.

The workflow consists of four main stages (Figure 1). First, climate variables required for NatHERS weather files are extracted from representative climate model grid cells and transformed into a consistent set of hourly meteorological variables. Second, projected climate change signals are transferred onto the historical NatHERS observations using Quantile Delta Change (QDC) scaling (Irving and Macadam 2024). Third, NatHERS-compatible meteorological variables are derived from the future-adjusted data. Finally, future TMY and XMY weather files are generated for building energy simulation.

A detailed description of the methodology is provided in the project's technical report (Hoffmann et al 2026).

2.1 Extracting suitable data for point locations from gridded model output (Methodology Step 1)

Historical reference conditions were represented using Version 3 of the 2016 NatHERS multiyear climate dataset, comprising hourly meteorological time series for 1990–2015 at designated NatHERS reference locations (Liley, 2017). The NatHERS weather files are converted from local standard time to Coordinated Universal Time (UTC) and stored in NetCDF format prior to facilitating direct comparison with the regional climate projections and subsequent bias-adjustment.

Future climate data were obtained from the Bureau of Meteorology Atmospheric Regional Projections for Australia (BARPA-R; Su et al., 2022b), which dynamically downscales an ensemble of seven CMIP6 global climate models (Table 1). Future conditions are represented using the low emissions (SSP1-2.6) and high emissions pathways (SSP3-7.0) available from BARPA-R and three future 20-year periods centred on the 2030s, 2050s and 2070s. These shared socio-economic pathways (SSPs) (O'Neill et al. 2016) represent the plausible upper and lower range of future climate projections considered 'good practice' to assess (DCCEEW, 2026), and high-resolution data is readily available. While SSP5-8.5 is now considered implausible under current policies (Van Vuuren et al., 2026), the plausible high-emissions pathway SSP3-7.0 still encompasses temperatures comparable to those projected under SSP5-8.5 within its very likely range (DCCEEW, 2026), ensuring that high-end 'worst case' warming remains represented in the files.

Meteorological variables required for NatHERS - including air temperature, specific humidity, wind speed and direction, atmospheric pressure, cloud cover and solar radiation - were extracted or derived from the BARPA-R simulations. As the NatHERS locations represent specific weather stations rather than model grid cells, representative BARPA-R grid cells were extracted using objective criteria based on station elevation, land fraction (important for coastal locations) and proximity to station location. This improved the physical correspondence between each NatHERS reference location and its selected BARPA-R grid cell compared with using geographical proximity alone. A point-to-grid mismatch nevertheless remains, particularly near coastlines and in areas of complex topography.

Prior to bias adjustment, BARPA-R variables were transformed where necessary to match the meteorological quantities represented in the NatHERS observational dataset. This included the calculation of station pressure, model cloud cover, model wind direction and global horizontal solar irradiance from the available BARPA-R variables for data preparation and comparison (Table 1), thereby ensuring that physically equivalent quantities were compared during the subsequent bias-adjustment procedure. BARPA-R wind direction and cloud cover were not subsequently used to adjust the corresponding NatHERS variables, as explained in Section 2.3.

Table 1: Global climate models and their runs downscaled by BARPA-R at 17km spatial resolution for SSPs 1-2.6 and 3-7.0.

GCM	Run	SSP	Resolution	Variables
ACCESS-ESM1-5	r6i1p1f1	SSP1-2.6 SSP3-7.0	17km, hourly	• Near-surface Air Temperature [tas] • Near-surface Specific Humidity [huss] • Near-surface Wind Speed [sfcWind] • Eastward Near-Surface Wind [uas] • Northward Near-Surface Wind [vas] • Surface Direct and Diffuse Downwelling Shortwave Radiation [rsdsdir, rsdsdif] • Sea Level Pressure [psl] • Cloud Cover Fraction [clt]
ACCESS-CM2	r4i1p1f1			
CESM2	r11i1p1f1			
CMCC-ESM2	r1i1p1f1			
EC-Earth3	r1i1p1f1			
MPI-ESM1-2-HR	r1i1p1f1			
NorESM2-MM	r1i1p1f1			

2.2 Climate change signal application using QDC approach (Methodology Step 2)

The projected climate change signal was applied to the observed historical weather using the Quantile Delta Change (QDC) method (Irving and Macadam, 2024). QDC adjusts the NatHERS observational record according to the changes projected by BARPA-R, rather than replacing the observations with modelled weather. For each variable, the distribution of values was divided into 100 quantiles, and the projected change between the BARPA-R historical and future periods was calculated at each quantile. This change was then applied to the corresponding quantile of the observed NatHERS data. The adjustment was undertaken separately for each calendar month and hour of the day, using a moving three-hour window to provide a sufficient sample while retaining the diurnal cycle. Additive adjustments were used for air temperature, while proportional adjustments were used for humidity, wind speed, pressure and solar radiation. This approach retains the temporal sequencing of the historical NatHERS data while incorporating the distributional climate-change signal projected by each model, scenario and future period. It does not independently represent projected changes in the timing, sequencing or persistence of weather events. Consequently, changes in heatwave duration are constrained by the temporal characteristics of the historical sequence and should be interpreted with particular caution.

2.3 Transformation of variables (Methodology Step 3)

Following the QDC step, the variables were converted into the final form required by the NatHERS weather-file format. Where necessary, related meteorological quantities were calculated from the adjusted variables; for example, relative humidity and dew-point temperature were derived from air temperature, specific humidity and pressure. Additional processing ensured that pressure, wind and solar-radiation variables used the units and

conventions required by NatHERS. Some variables could not be adjusted using QDC because they are represented as discrete categories rather than continuous quantities. In particular, cloud cover is recorded in oktas and wind direction in 16 compass sectors. The corresponding hourly values from the historical NatHERS record were therefore retained. Consequently, the generated files do not incorporate possible future changes in wind direction or cloud cover, and adjustment of wind speed independently of wind direction may alter their historical relationship.

2.4 Generation of prototype TMY and XMY files (Methodology Step 4)

Two types of prototype future weather files were generated for 11 locations across Australia representing different climate zones: Typical Meteorological Year (TMY) files and Extreme Meteorological Year (XMY) files.

2.4.1 Typical Meteorological Year (TMY) files:

A Typical Meteorological Year (TMY) file is a synthetic weather dataset constructed to represent the average climatic conditions of a specific location over a given historical period. It is composed of 12 months selected from different years in the multiyear record, each chosen to be “typical” for that calendar month based on how closely it matches long-term statistical averages. TMY files preserve realistic daily and hourly variability while filtering out extreme or anomalous years, allowing for consistent and comparable building performance assessments under standard climate conditions.

In this study, we generate the TMY following established methodologies described by Marion and Urban (1995) and Wilcox and Marion (2008), and adopted by CSIRO (Ren, et al, 2021). A core component of this methodology is the Finkelstein–Schäfer (FS) statistic (Finkelstein and Schäfer, 1971). For each calendar month, the cumulative distribution functions of candidate months were compared against the long-term climatological distribution for multiple meteorological variables. The FS statistic quantified the average absolute difference between the two distributions, with lower values indicating greater representativeness. Weighted FS scores (see Liley, 2017 for details) were then used to rank candidate months, and the most representative month was selected following additional screening of mean conditions and persistence characteristics (Wilcox and Marion 2008, Machard et al. 2024). The selected months were concatenated to produce a synthetic year representative of the long-term climate.

The selection procedure was independently applied to the historical baseline (1995–2014), and to each bias-adjusted future hourly dataset, i.e. for each of the 3 20-year periods. The resulting historical and future TMYs therefore represent the typical climatic conditions of their respective periods using an internally consistent selection procedure. In other words, candidate months were selected according to their representativeness of the future period itself, rather than by imposing the historical TMY month selections on future climates. Consequently, the years contributing individual months to a future TMY may differ among climate models, scenarios and future periods. This procedure preserves two distinct sources of information: the projected change in the meteorological distributions contained in the bias-adjusted future datasets; and the realistic hourly sequence of each selected candidate

month. Separate TMYs were produced for every combination of location (11), climate model (7), emissions scenario (2) and future period (3) resulting in 462 future TMY weather files, in addition to the historical TMYs.

2.4.2 eXtreme Meteorological Year (XMY) files

Heatwaves can be defined in a variety of ways depending on their intended application. For example in Australia, the Bureau of Meteorology's Excess Heat Factor uses a three-day mean of daily mean temperature and accounts for both exceedance of a location-specific climatological threshold and short-term acclimatisation relative to conditions during the preceding 30 days to consider the population adaptation to current conditions (Nairn and Fawcett, 2014). Perkins and Alexander (2012) defined two criteria, based on fifteen days moving average around the daily minimum and maximum temperatures. For XMY selection, fixed location-specific percentile thresholds were preferred because they allow event intensity, duration and cumulative thermal loading to be compared consistently across climate models, future periods and emissions scenarios. The percentile-based framework was adapted from Ouzeau et al. (2016) and has subsequently been applied in building-resilience studies by Machard et al. (2020, 2024). The two approaches are complementary and serve different purposes. We have adopted Ouzeau et al.'s heatwave dimensions concept to generate extreme weather files from the same set of hourly weather datasets for Australia that can be used within existing building assessment tools.

Heatwaves were identified using daily mean temperature and location-specific percentile thresholds derived from the 1995–2014 historical reference period. A qualifying event was required to contain at least one day above the 99.5th-percentile peak threshold and to last for at least three days at every location. The 97.5th percentile defined the event start and end threshold, while the 95th percentile was used as an interruption threshold. Following Ouzeau et al. (2016), an event ended when daily mean temperature remained below the 97.5th-percentile threshold for three consecutive days or fell below the 95th-percentile threshold for a single day. This rule allows one or two days between the 95th and 97.5th percentiles to occur without dividing a persistent heatwave into separate events.

Three representative XMY files - to capture the three distinct characteristics of heat events - are generated for each location, model, scenario and time period. Unlike the synthetic TMY files, each XMY comprises a continuous 12-month period containing a selected heatwave from the relevant 20-year future-adjusted series on the basis of the three heatwave characteristics each representing a different dimension of heatwave risk among all identified heatwave events within the analysis period:

1. **The most intense heatwave**, defined as the heatwave containing the highest single-day mean temperature within the analysis period.
2. **The most severe heatwave**, defined as the heatwave with the largest cumulative normalized heat stress, calculated as the sum of daily mean temperature exceedances above the 97.5th percentile threshold and normalized by the difference between the 99.5th and 97.5th percentile temperatures.

3. **The longest heatwave**, defined as the heatwave with the greatest number of consecutive days exceeding the 97.5th percentile threshold, including permitted interruption days under the 95th-percentile rule

The period does not necessarily run from January to December; where an event crosses the calendar-year boundary, the heatwave is retained as a continuous sequence spanning both years. These definitions are based on earlier work (Ouzeau et al., 2016), adopted by Machard et al. (2024) for building resilience research and recommended in the recent CSIRO review to support stress testing of building performance under future extreme heat conditions (Ren, 2025). Each XMY retains a continuous 12-month weather sequence before, during and after the selected heatwave, including antecedent conditions, overnight temperatures, humidity, wind and solar radiation. Winter months are retained as part of this sequence but do not influence which heatwave is selected. An XMY should therefore be interpreted as a weather sequence containing a selected extreme heat event, rather than as a period that is consistently hot or representative of cold extremes. It is possible for the same heatwave event to satisfy multiple selection criteria and therefore be identified as the most intense, most severe, and longest-duration heatwave. In some locations and climate periods, a single heatwave may consequently be selected for more than one XMY category. However, for consistency and ease of application in building performance assessments, the Most Intense, Most Severe, and Longest Duration XMYs are currently provided as separate weather files, even when they are derived from the same underlying heatwave event. Consequently 21 XMY weather files (3 XMY types x 7 climate models) were generated for each location, scenario and future period.

Because the future hourly weather datasets preserve the underlying historical weather chronology, historical heatwave events remain embedded within the future climate. However, projected warming may also cause previously non-heatwave periods to exceed the historical thresholds, resulting in additional heatwave events and potentially different XMY selections. Because the XMY method uses fixed percentile thresholds rather than the Bureau's Excess Heat Factor, the identified events are not directly equivalent to heatwaves reported using the Bureau's heat-health framework (Nairn and Fawcett, 2014). The XMY events should therefore be interpreted as building stress-test events selected using the adopted Ouzeau et al. framework. The resulting weather files are formatted in NatHERS compatible formats and include comprehensive metadata in their names including the climate model, emissions scenario, time period, and TMY or XMY method used.

3. Representing the range of possible future climate conditions

3.1 Characteristics of the prototype files

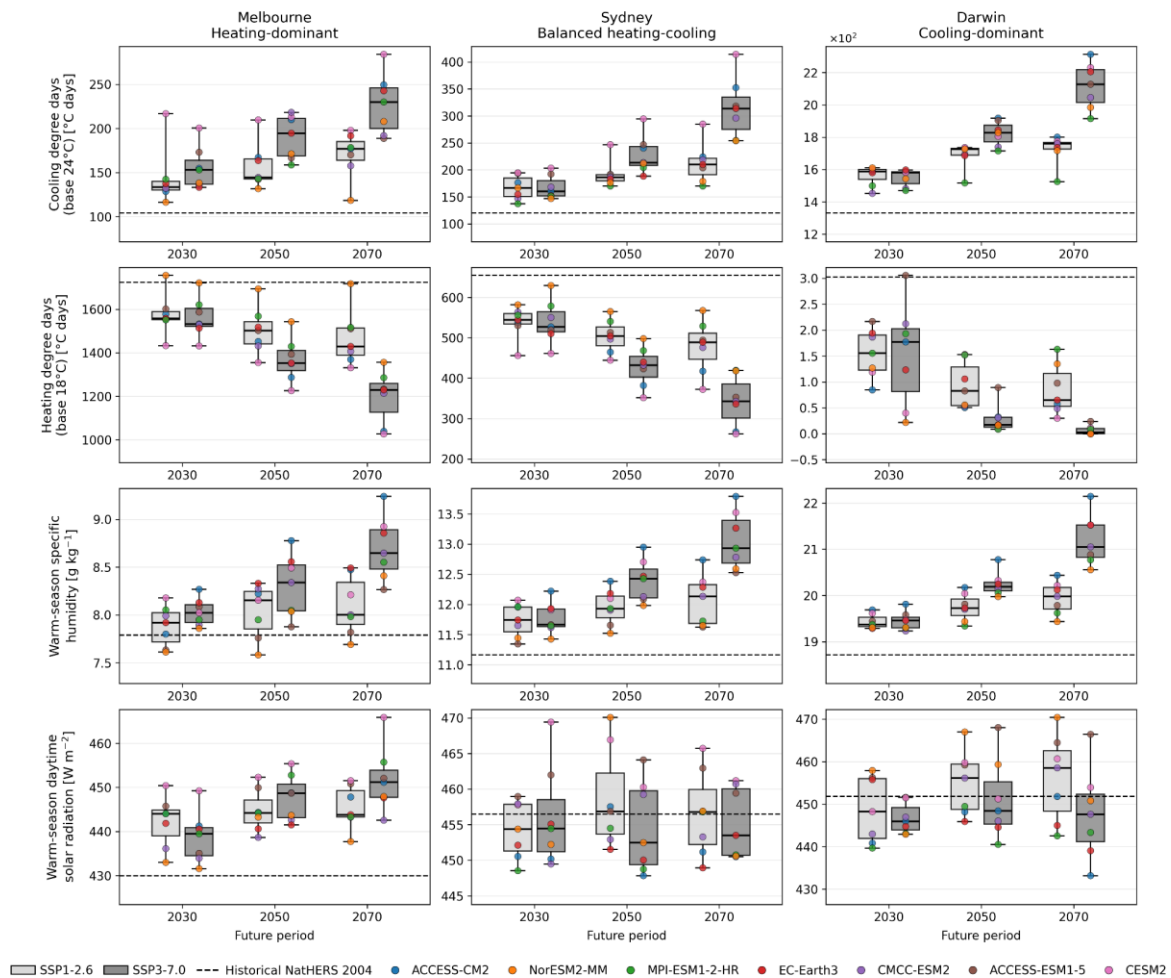


Figure 4: Climate characteristics of TMY files for Melbourne (heating-dominant), Sydney (balanced heating-cooling) and Darwin (cooling-dominant). From top row to bottom: Cooling degree days with a comfort level of 24°C, heating degree days with a comfort level of 18°C, warm-season (October to March) specific humidity and warm-season daytime solar radiation (when solar radiation exceeds 10W/m²). Boxplots are paired for SSP1-2.6 and SSP3-7.0 for each future time period, with the thick black line representing the multi-model median, upper/lower box edges are the 25th/75th percentile ensemble range and whiskers show the hottest/coolest, most/least humid, and most/least sunny climate model. The horizontal dashed line represents conditions from NatHERS TMY files.

3.1.1 Characteristics of future Typical Meteorological Year (TMY) weather files

Figure 4 summarises the projected characteristics of the future TMY weather files for representative heating-dominated (Melbourne), balanced (Sydney) and cooling-dominated (Darwin) climates. These locations illustrate the range of projected responses across Australian climate zones, while results for all remaining NatHERS locations are provided in Appendix A (Figures A1-A3). Unless otherwise stated, changes refer to the climate-model ensemble median relative to the historical NatHERS weather file. Across all climate types, future TMY weather files exhibit increasing cooling demand and decreasing heating demand. The magnitude of these changes generally increases from the 2030s to the 2070s and is consistently larger under SSP3-7.0 than SSP1-2.6. Projected changes in warm-season specific humidity are generally consistent in direction within the ensemble, whereas changes in daytime solar radiation are smaller and less spatially uniform. Both variables are

influenced by moist and cloud processes that are more difficult to represent than temperature, and their projected changes are therefore interpreted with greater caution.

Cooling degree days

Cooling degree days (CDD) increase in all three representative climates and across all climate models. The largest absolute increase occurs in Darwin, where the ensemble median increases from approximately 1,330 °C days in the historical weather file to more than 2,100 °C days by the 2070s under SSP3-7.0, an increase of approximately 60%. Sydney and Melbourne exhibit smaller absolute increases but larger proportional changes because of their lower historical cooling demand. By the 2070s, median CDD approximately doubles in Melbourne and increases by a factor of 2.6 in Sydney.

The ensemble spread also increases with the future time horizon, particularly under SSP3-7.0, indicating increasing divergence among climate models. Nevertheless, all models project increasing CDD across the representative locations, and similar behaviour is evident for the remaining NatHERS locations (Figures A1-A3), indicating a robust increase in future cooling requirements.

Heating degree days

Heating degree days (HDD) decrease consistently across all locations. The largest absolute reductions occur in Melbourne, where median HDD decrease by approximately 500 °C days (around 30%) by the 2070s under SSP3-7.0. Sydney exhibits a smaller absolute reduction but a larger proportional decrease of almost 50%. In Darwin, historical HDD are already negligible and decline to near zero in all future periods. Although this represents an almost complete loss of heating demand, the absolute change is only a few degree days.

Model spread increases through time, particularly for Melbourne, but all models consistently project declining heating demand. Similar reductions are evident across the remaining heating- and balanced-climate locations (Figures A1-A3), whereas tropical locations show little absolute change because heating demand is already minimal under the historical climate.

Warm-season specific humidity

Warm-season specific humidity increases across the three representative climates, with larger changes under SSP3-7.0 and towards the 2070s. Absolute increases are greatest in Darwin, where the ensemble median rises from approximately 18.7 to 21.1 g kg⁻¹ by the 2070s under SSP3-7.0. The corresponding increases in Sydney and Melbourne are approximately 1.8 and 0.8 g kg⁻¹, respectively. These changes represent increases of approximately 10–17% across the three climate types. The individual model results consistently indicate increasing specific humidity, although the magnitude of the change varies among models. Similar increases are evident for most of the remaining locations (Figures A1-A3).

Warm-season daytime solar radiation

Changes in warm-season daytime solar radiation are comparatively small and less consistent than changes in temperature- and humidity-related metrics. Median changes are generally within ±5% of the historical values and, for several locations, are comparable to the

spread among climate models. Melbourne exhibits a small positive shift by the 2070s, whereas Sydney shows little systematic change and Darwin exhibits a slight decrease under SSP3-7.0.

Unlike the other metrics, the ensemble distributions for SSP1-2.6 and SSP3-7.0 overlap substantially, indicating that scenario differences are small relative to model uncertainty. Similar behaviour is evident across the remaining locations (Figures A1-A3), suggesting that future changes in solar radiation are likely to play a secondary role compared with projected changes in air temperature and humidity.

Warm-season specific humidity and daytime solar radiation were included because project users identified both variables as relevant to latent cooling demand, solar heat gains and building performance. However, these projections should be interpreted with greater caution than the temperature-derived metrics. At its approximately 17 km resolution, BARPA-R does not explicitly resolve deep convection, while humidity and surface radiation depend strongly on moist atmospheric, cloud and convective processes that require parameterisation and remain important sources of model uncertainty (Howard et al., 2024; Prein et al., 2015). Evaluations of climate models have identified persistent biases in simulated humidity and substantial model spread and biases in surface solar radiation (Simpson et al., 2024; Vautard et al., 2021). Accordingly, the projected humidity increases and the smaller, less spatially consistent radiation changes are interpreted as indicative signals rather than tightly constrained estimates.

Model uncertainty and scenario dependence

Across all representative locations, the separation between SSP1-2.6 and SSP3-7.0 is modest in the 2030s but becomes increasingly distinct by the 2050s and particularly the 2070s. For CDD, HDD and humidity, the ensemble-median change generally exceeds the interquartile model spread, indicating that the climate-change signal is larger than differences among the seven climate models. Although model spread increases towards the end of the century, particularly for CDD in Melbourne and Darwin, the direction of change is consistent across all models. Results for the remaining NatHERS locations show the same overall behaviour (Figures A1-A3).

3.1.2 Characteristics of future eXtreme Meteorological Year (XMY) weather files

Figures 5 summarises the projected characteristics of representative XMY weather files for Melbourne, Sydney and Darwin. As for the TMY weather files, these locations represent the range of Australian climate zones, while the complete set of locations is presented in Appendix A (Figures A4-A6). It should be noted that the heatwave projections reported in this following section are based on definitions from Ouzeau et al. (2016) and adopted by Machard et al. (2024) for building resilience research. The XMY metrics comprise the longest-duration event, measured from the identified event start to end and including permitted interruption days; the most intense event, defined by the highest single-day mean temperature; and the most severe event, defined by the largest cumulative normalised temperature exceedance above the 97.5th-percentile threshold. Every qualifying event lasts at least three days, contains at least one day above the 99.5th-percentile threshold and is delimited using the 97.5th- and 95th-percentile rules described in Section 2.4.2. Heatwave frequency is calculated from the complete 20-year climate simulations and is included to

provide context on projected changes in heatwave occurrence (i.e. the number of projected heatwave events is not per year it is per 20 years). Therefore, the projections for the locations are not directly comparable to other heatwave projections reported elsewhere that are based on different definitions (e.g. [Queensland Future Climate Dashboard](#)).

The XMY results should also be interpreted in the context of uncertainty in the regional climate projections and the QDC methodology. Climate models differ in their representation of the processes controlling heatwave development and persistence (Hirsch et al. 2021), while QDC retains the historical temporal sequence rather than independently simulating future event sequencing. Confidence is therefore greater in the broad warming signal than in the timing, duration or detailed meteorological evolution of individual future heatwaves.

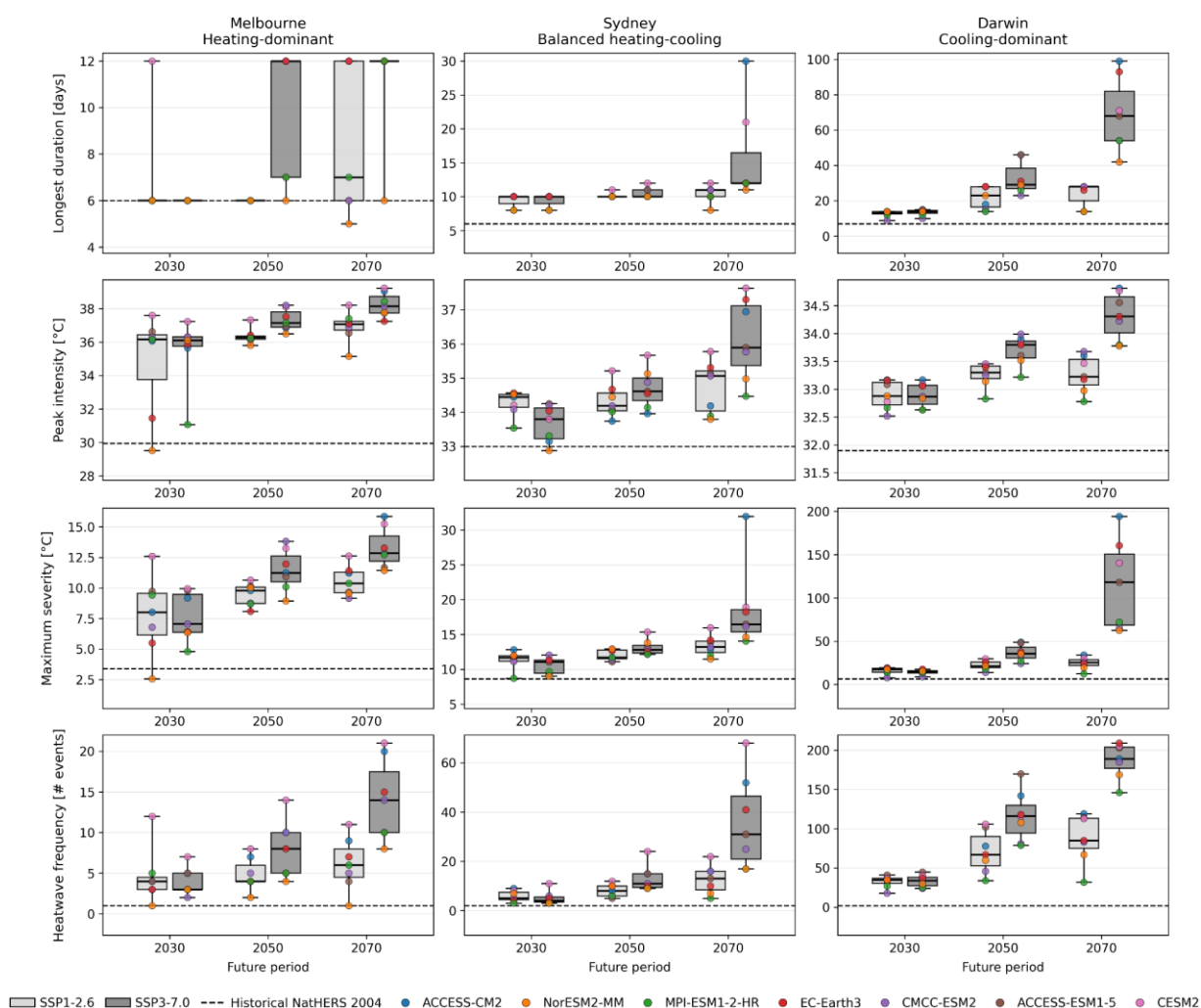


Figure 5: Climate characteristics of XMY files for Melbourne (heating-dominant), Sydney (balanced heating-cooling) and Darwin (cooling-dominant). From top row to bottom: longest duration in days, peak intensity in °C, heatwave severity in °C, heatwave frequency in number of events. Note, heatwave frequency is calculated from the full 20-year climate simulation rather than the selected XMY weather file. The remaining metrics describe the heatwave represented within the selected XMY weather file. Boxplots are paired for SSP125 and SSP370 for each future time period, with the thick black line representing the multi-model median, upper/lower box edges are the 25th/75th percentile ensemble range and whiskers show the hottest/coolest, climate model. The horizontal dashed line represents conditions from NatHERS (historical) XMY files.

Longest heatwave duration

Projected changes in the duration of the longest heatwave are more variable than changes in frequency. In Melbourne, the representative XMY heatwave increases from approximately six days in the historical weather file to around 12 days by the 2070s under SSP3-7.0. Sydney exhibits a similar increase, while Darwin shows much larger changes, with median durations approaching 70 days and individual models exceeding 90 days.

The larger spread in Darwin demonstrates that future persistence of extreme heat is considerably more uncertain than changes in heatwave frequency. Similar variability is evident across the remaining locations (Figures A4-A6). QDC retains the historical temporal sequencing while changing the statistical distributions, and does not independently simulate projected changes in atmospheric persistence. Duration should therefore be interpreted with greater caution than the broad warming signal and considered alongside peak intensity and cumulative severity.

Peak intensity

Peak heatwave intensity increases across all representative climates, with both the magnitude of change and model spread increasing towards the end of the century. Melbourne exhibits one of the largest absolute increases, with median peak intensity increasing substantially by more than 8°C by the 2070s under SSP3-7.0. Sydney increases by approximately 3°C, whereas Darwin increases by around 2.5°C despite already having much higher historical peak temperatures.

The larger increase in Melbourne highlights that cooler climates can experience substantial changes in the intensity of extreme heat, even though their absolute temperatures remain lower than those in tropical regions. Similar behaviour is evident for Hobart and Canberra (Figure A4), demonstrating that changes in peak intensity are not confined to the warmest climates.

Heatwave severity

Maximum heatwave severity exhibits the largest overall response of all XMY metrics. Compared with the historical NatHERS XMY weather files, median severity increases by approximately a factor of three in Melbourne, doubles in Sydney, and increases by more than an order of magnitude in Darwin under SSP3-7.0 by the 2070s. The Darwin ensemble also shows the largest model spread, with projected severity ranging from approximately 60 to almost 200°C among individual models.

Compared with peak intensity, severity shows stronger separation between emissions scenarios and substantially larger increases in both the ensemble median and model spread. This reflects the cumulative nature of the metric, which integrates both the magnitude and persistence of heat making heatwave severity a useful stress-test indicator of cumulative thermal loading. However, the magnitude of the projected severity remains sensitive to the selected model, the historical temporal sequence and the adopted heatwave definition. Similar behaviour is observed across the remaining NatHERS locations (Figures A4-A6), indicating that future XMY weather files represent not only hotter extreme conditions but also substantially greater cumulative thermal stress.

Heatwave frequency

The number of projected heatwave events reported in this section is calculated from the complete 20-year climate simulations and is included to provide context on projected changes in heatwave occurrence (i.e. The number of projected heatwave events is not per year, it is per 20 years).

Heatwave frequency increases substantially in all representative climates, although the magnitude of change differs markedly between locations. Darwin exhibits the largest increase, with the ensemble median rising from only two events in the historical climate to almost 100 heatwave events during the 20-year period centred on the 2070s under SSP3-7.0, representing almost a hundred-fold increase. Sydney increases from approximately one to more than 30 events, while Melbourne increases from one to approximately 14 events.

Because historical event numbers are very small for many locations, relative changes are better expressed as multiplicative factors rather than percentages. The model spread also increases markedly towards the end of the century, particularly in Darwin, where some models project more than 200 heatwave events during the 20-year period. Despite this increasing spread, every model projects higher heatwave frequency in the future climate. Similar increases are evident across the remaining NatHERS locations (Figures A4-A6).

Model uncertainty and scenario dependence

The coloured markers show the individual climate-model results and demonstrate that uncertainty in the magnitude of future change increases with time. The spread is greatest for heatwave frequency, longest duration and maximum severity, whereas peak intensity is generally more tightly constrained. Under SSP3-7.0 in the 2070s, for example, heatwave severity ranges from 11.4 to 15.9°C in Melbourne, 14.1 to 32.0°C in Sydney and 62.6 to 194.3°C in Darwin. The corresponding longest-duration ranges are 6–12, 11–30 and 42–99 days. Thus, although all seven models project increasing heatwave activity for most metrics and locations, the magnitude of the projected extreme can differ substantially among models. Comparable inter-model divergence is evident for other tropical and inland locations in the appendix figures.

Differences between models are generally larger for the XMY metrics than for the TMY metrics because the former depend on individual extreme events and their temporal sequencing rather than mean climate conditions. The broad and sometimes asymmetric distributions also show that the ensemble maximum can lie well above the ensemble median. For example, under SSP3-7.0 in the 2070s, Sydney's median longest duration is 12 days but one model produces 30 days, while median maximum severity is 16.5°C compared with an ensemble maximum of 32.0°C. In Darwin, projected severity spans more than 130°C across the ensemble. These upper-tail results are relevant for stress testing but should not be interpreted as ensemble-representative projections.

Differences between SSP1-2.6 and SSP3-7.0 remain relatively small in the 2030s and often overlap with the inter-model spread. Scenario separation becomes clearer by the 2050s and is strongest in the 2070s, particularly for frequency, duration and severity. For example, Darwin's median 2070 heatwave frequency is 85 events per 20 years under SSP1-2.6 and

189 under SSP3-7.0, while median maximum severity increases from 25.6 to 118.3°C. Peak intensity shows a smaller but consistent scenario response. This indicates that the emissions pathway becomes increasingly important for long-term extreme-heat exposure, although model uncertainty remains substantial for the most extreme event characteristics.

The longest, most intense and most severe XMY files are selected independently within each climate model, location, emissions scenario and future period. The seven models therefore produce seven files for each XMY category rather than a single file selected from the ensemble maximum. The individual model results show that one model may produce substantially greater heatwave duration or severity than the others, making user selection among the available files consequential for subsequent building simulations. Upper-tail model results can be useful for stress testing but should not be interpreted as ensemble-representative projections. Guidance is therefore needed to help users distinguish between a central ensemble result and a high-end stress-test application. The individual model markers and full-location appendix figures are therefore important for distinguishing selections supported by several models from those driven by an isolated upper-tail result. Heatwave frequency is not subject to this XMY-selection procedure because it is calculated separately from each complete 20-year simulation.

4. Testing of prototype future TMY and XMY files in residential building simulation applications

The aim of the testing was to elicit the expert opinion of building simulation practitioners (building designers and NatHERS assessors) to assess if the prototype files are fit-for-purpose for residential building assessments. In this context, fit-for-purpose means producing simulation-ready weather files that (i) are compatible with industry-standard tools, (ii) realistically represent projected climate conditions including extremes, and (iii) produce meaningful and interpretable building-performance outputs.

We asked the building simulation practitioners the following questions:

1. Are the prototype files in a format compatible with NatHERS accredited building simulation software, and do they contain the required variables for building simulation applications, suitable emissions pathways and timeframes?
2. For energy efficiency and thermal comfort assessments, do the prototype files provide a useful weather sequences for exploring a range of projected future typical and heatwave conditions?

To answer these questions, the building simulation practitioners used the files in NatHERS accredited residential building simulation software (<https://www.nathers.gov.au/accredited-software>) including HERO, FirstRate5, and AccuRate in the same way they would typically assess a building design for NatHERS compliance e.g. energy efficiency. The resulting test simulations ranged from modelling a small selection of TMY files for one dwelling type and one location, to using all the prototype TMY files for all 11 locations, both SSPs and all 7 climate models. Files were evaluated for a range of NatHERS dwellings (Ren et al in prep, Strategy Policy Research and RED Sustainability, in prep). In this paper we chose to explore the simulation results for a common 4-bedroom double storey, NatHERS standard 500 SAP house (see table 3 for specifications), for all the prototype TMY files, for all 11 locations, both SSPs and all 7 climate models, with comparisons to the current (historical) NatHERS file and the existing future weather, CSIRO Projected weather files (Ren et al. 2021).

Table 3: Specifications of 500 SAP NatHERS residential building archetype

House type	External walls	Roof type	Floor	Windows	Number of Bedrooms	Total area (m ²)
500 SAP	Brick veneer, double brick	Metal deck, R3 insulation	110 mm concrete, 375mm waffle pod	Timber frames, double grading, Argon fill, clear	4	265.52, detached, double storey

As this is the first time these building simulation practitioners have had information on heatwaves available, we have explored with testers how to apply the XMY files. Testing ranged from using the XMY files to ‘stress test’ the energy efficiency of building design to testing for occupant thermal comfort.

4.1. Testing of prototype TMY and XMY files

The prototype TMY and XMY weather files were tested with NatHERS-accredited building simulation software by building designers and NatHERS assessors. Testing aimed to evaluate three key questions:

1. Whether the files were technically compatible with existing building simulation software.
2. Whether the files contained the information required for residential building performance assessment.
3. Whether practitioners could practically apply the files within existing design and assessment applications.

Testing confirmed that both the TMY and XMY prototype files were technically fit for purpose and compatible with NatHERS-accredited building simulation software. Practitioners confirmed that the files contained the variables required for residential building thermal performance modelling and could be successfully integrated into existing simulation applications.

Participants also considered the selected future time periods to be appropriate for decision-making. The 2030s were generally viewed as a reasonable representation of the 'current' climate conditions and the 2070s the extent of the expected operational life-span of a house constructed today.

The XMY files provided additional value by allowing practitioners to explore the impacts of extreme heat events on building performance and occupant thermal comfort. This capability does not currently exist within the standard NatHERS weather files, which are based on typical weather conditions rather than extreme events.

The main challenge identified during testing was the large number of weather files generated for each location. Multiple files were required to represent the range of future climate conditions projected from the various climate models, under different emissions scenarios (SSPs) and time periods as well as including heatwaves. In contrast, building simulation practitioners are accustomed to selecting a single weather file for NatHERS assessments.

To simplify file selection, climate models were ranked as "coolest", "median", and "hottest" for each location. While practitioners considered this useful, most reported that this alone did not provide sufficient guidance for routine application. Even after narrowing the model selection, users were still faced with multiple TMY and XMY files for each location and future period. Many practitioners indicated that assessing multiple files was impractical within current commercial applications.

Testing also highlighted two artefacts of the XMY methodology that required further explanation. For some combinations of location, climate model, emissions scenario and time period, a single heatwave event simultaneously represented the most severe, most intense and longest event. In these cases, the three corresponding XMY files were identical, reducing the practical distinction between the different heatwave characterisations.

The heatwave identification methodology used for XMY generation also differs from the way the current definition the Bureau of Meteorology uses to forecast and record heatwaves in Australia (Narin and Fawcett, 2014) (refer to section 2.4). The XMY method uses fixed, location-specific percentile thresholds to characterise event intensity, duration and cumulative severity, whereas the Excess Heat Factor also accounts for short-term acclimatisation relative to the preceding 30 days. As a result, historically significant heatwaves identified using the EHF approach are not always selected as XMY events. For example, while the January-February 2009 heatwave is widely regarded as Melbourne's most severe recorded heatwave, it was not selected as one of the historical XMY files. This can make historical XMY files difficult to relate to well-known observed heatwaves and means that the XMY projections are not directly comparable with projections based on Excess Heat Factor. The two approaches serve different purposes: Excess Heat Factor supports heat-health monitoring, while the XMY method was selected to provide consistent building stress-test events across models, scenarios and future periods.

As described in section 3, the use of a different heatwave definition than the Bureau of Meteorology uses to forecast and record heatwaves in Australia (Excess Heat Factor, Narin and Fawcett, 2014) also means the projections of heatwaves in the XMY files, cannot be directly compared with how they are reported elsewhere (e.g. [Queensland Future Climate Dashboard](#)), so this has the potential to cause confusion.

4.1.1 Future building simulation results

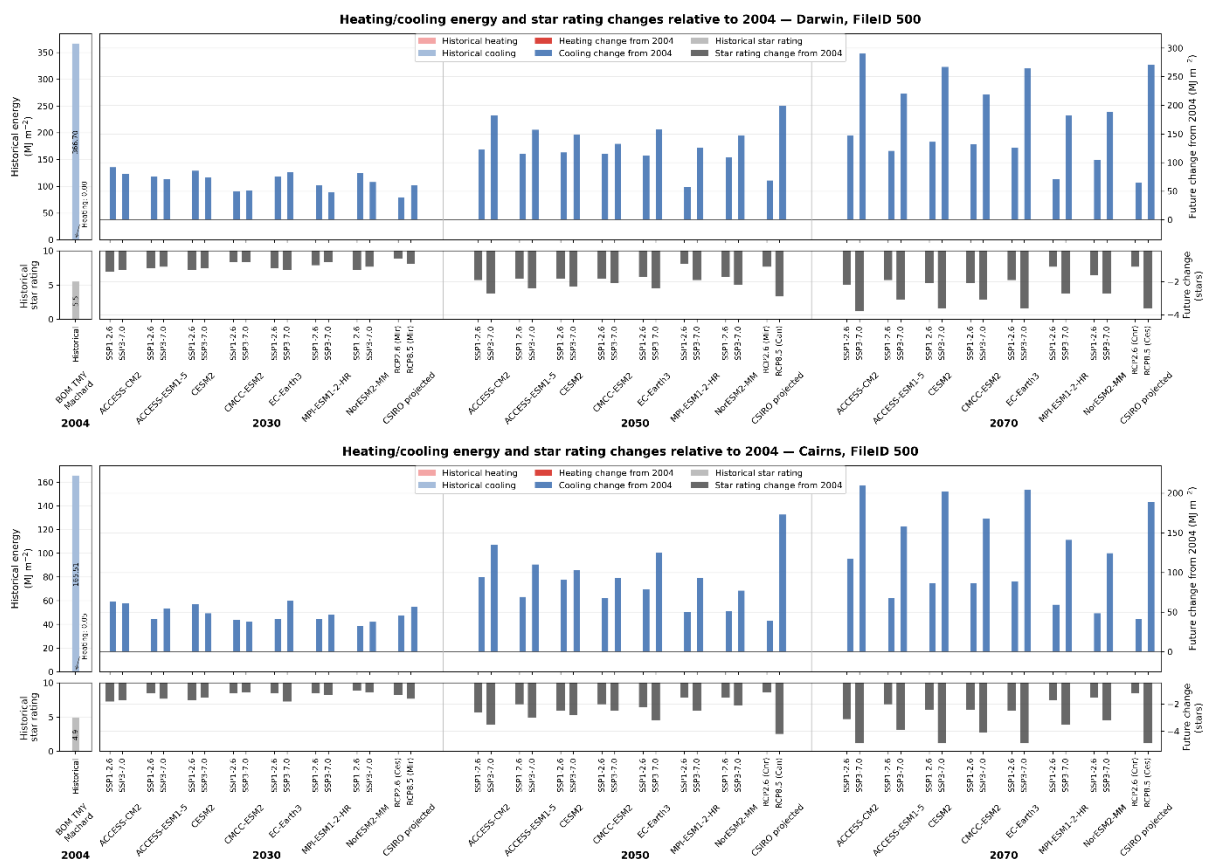
The results of the simulations of the prototype future TMY files for all 11 locations, both SSPs and all 7 GCMs for the standard NatHERS SAP 500 dwelling are shown for each location in Figures 10, 11 and 12. The simulations are comparing heating and cooling loads for prototype future TMY files, for both SSPs and all 7 climate models against the historical prototype TMY files (that are generally equivalent to current NatHERS files) and the CSIRO projected weather files. The consequent star rating increases or decreases using the future prototype TMY files are also compared relative to the current National Construction Code (NCC) 2022 NatHERS star ratings. It is important to note that changes in star ratings presented here are provided as an indication of the magnitude of change. Results should not be interpreted as indicative of future regulatory outcomes, as star ratings are a comparison with benchmark star bands, which are routinely updated when new weather files are introduced.

Overall, across all climate types, although the magnitude of change varies between GCMs and the 2 SSPs, especially after the 2050s, the results show a pattern of reduced heating demand, and increased cooling demand in the future. The changes vary regionally, so we have grouped the results in climate regions.

For **highly cooling-dominant locations** in Northern Australia, such as Darwin, Cairns, Brisbane, and Longreach, energy demand remains overwhelmingly driven by cooling under future climates. Darwin and Cairns, both tropical climates, have negligible heating requirements and show large increases in cooling demand across all future periods, scenarios, and climate models. Longreach and Brisbane, both sub-tropical climates, retain

only a small heating component, however, this becomes increasingly negligible over time as cooling dominates more strongly. There is variation across the climate models compared to the historical prototype TMY files.

Brisbane has the highest inter-model variation with the hottest model CESM2 under the highest emissions SSP3-7.0 showing a cooling increase of 312% compared to the historical prototype TMY files. The coolest model, MPI ESM1-2-HR, shows only 186% for the same SSP3-7.0 and even less cooling required (75%) under lower scenario SSP1-2.6. Currently, heating accounts for about 8.6% of total energy demand in Brisbane. Under future climate conditions (SSP3-7.0, 2070s), this small heating component declines by over 85% for the hottest model, CESM2, and the CSIRO projected weather files, making heating demand almost negligible (0.58 and 0.5 MJ/m² annually, respectively). However, there is a range, with the cooler models (for example, MPI-ESM1-2 MM) suggesting a 45% reduction for SSP3-7.0 and a 41% reduction for SSP1-2.6. All four locations experienced a consistent reduction in star ratings by the 2070s. These cooling load increases would translate into reductions of more than - 4.0 stars relative to the current NCC 2022 NatHERS star bands for Cairns and Brisbane.



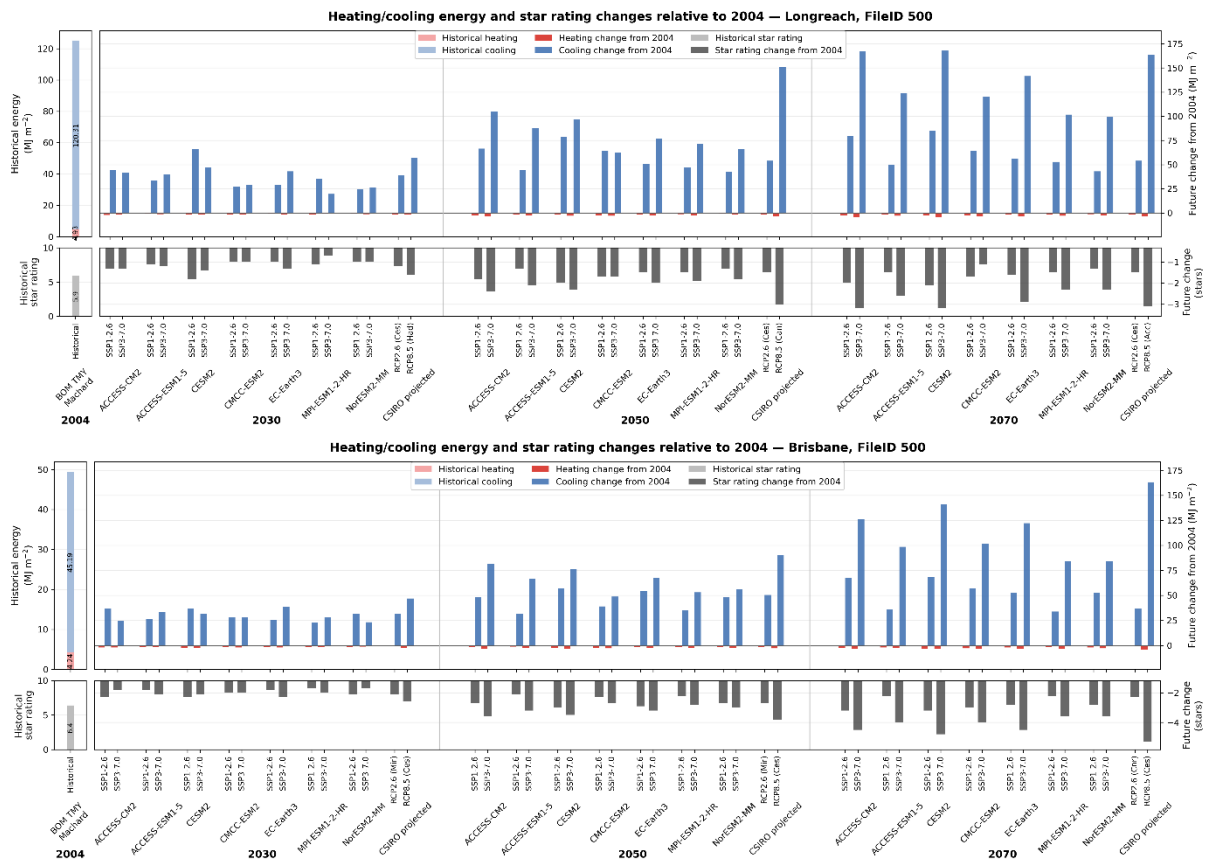


Figure 10: Comparing heating and cooling loads and star ratings for prototype future TMY files, both SSPs and all 7 climate models with historical TMY files and the CSIRO projected weather files for the 500 SAP standard NatHERS house type for presently cooling-dominated locations Darwin CBD, Northern Territory, Cairns CBD, Brisbane CBD and Longreach CBD, Queensland. Note the star ratings comparison in the future is relative to the current NCC 2022 NatHERS Star bands.

For currently balanced heating–cooling climates **temperate to sub-tropical locations** including Sydney, Perth, Adelaide, and Mildura, a clear warming-driven shift is projected across all climate models and scenarios through to the 2070s. This shift is characterised by a reduction in heating demand and an increase in cooling demand. Across the climate models, ACCESS-CM2 and CESM2 consistently produce higher cooling demand, particularly under SSP3-7.0, and Sydney shows the strongest increase in cooling by 369% and 442% respectively. Sydney also shows the greatest inter-model variability with the colder models (e.g. NorESM2-MM) showing an increase of 183% for SSP3-7.0 and 70% for SSP1-2.6. Notably the CSIRO projected weather files show a much lower increase of 51% for SSP1-2.6. Star ratings show a slight decline by the 2030s, followed by a marked reduction towards the 2070s, particularly under SSP3-7.0. The large cooling load increases for Sydney would translate to an almost -5.0 stars change relative to the current NCC 2022 NatHERS star bands.

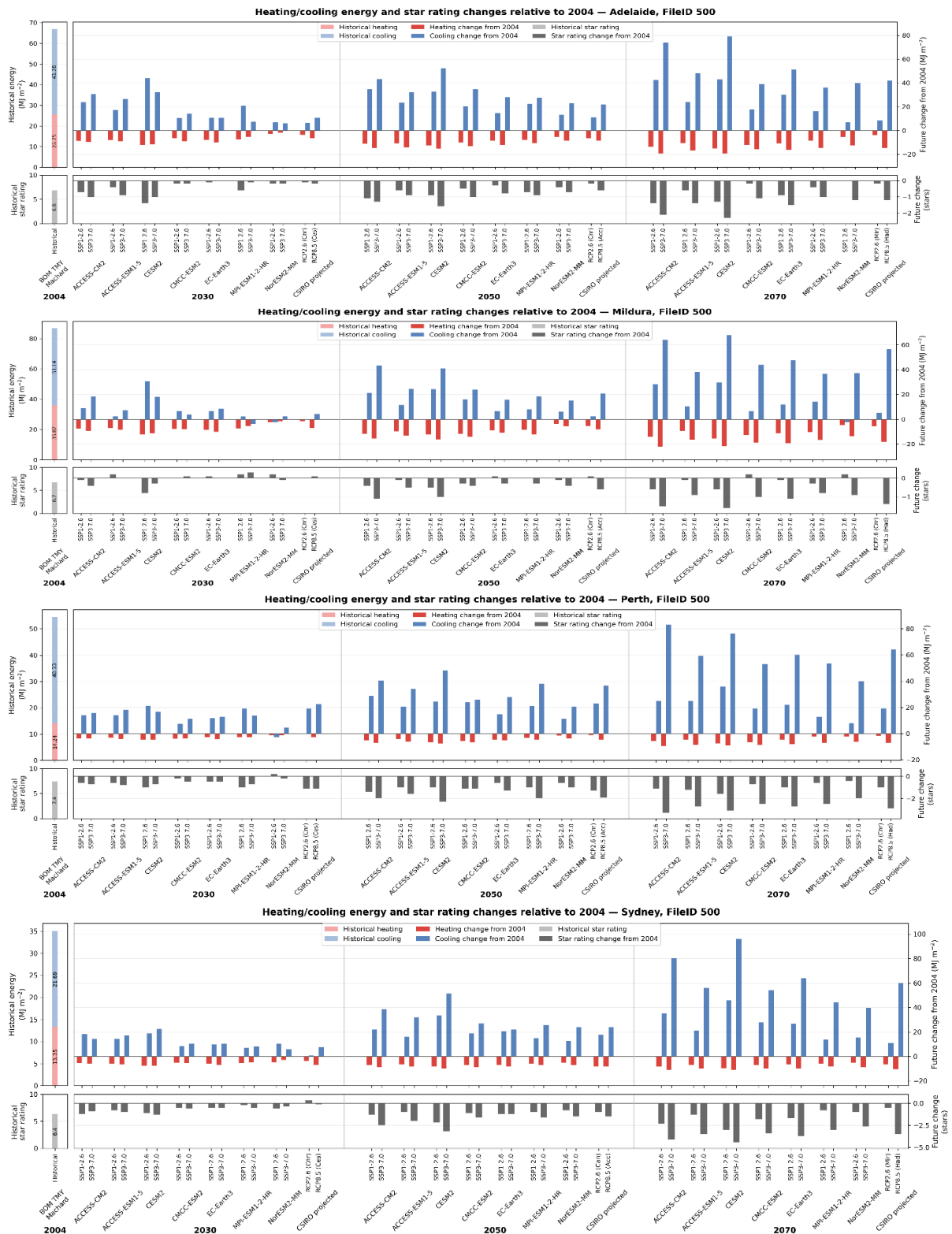


Figure 11: Comparing heating and cooling loads and star ratings for prototype future TMY files, both SSPs and all 7 climate models with historical TMY files and the CSIRO projected weather files for the 500 SAP standard NatHERs house type for presently balanced heating-cooling climates for the 500SAP standard NatHERs house type for Sydney (Mascot), NSW, Mildura CBD, Victoria, Perth CBD, WA and Adelaide CBD, SA. Note the star ratings comparison in the future is relative to the current NCC 2022 NatHERs Star bands.

Southern Australian cities, including Melbourne, Hobart and Canberra, are currently characterised by **cold temperature climates and heating-dominant energy profiles**. Under future climate projections, all three locations exhibit a consistent warming-driven shift, with heating demand decreasing substantially and cooling demand increasing from a low base. However, the reduction in heating generally outweighs the increase in cooling, resulting in a net decline in total energy demand. This reduction in total energy demand translates into higher star ratings, in clear contrast to northern and milder climates where total demand increases over time. This assessment is for ‘typical’ or average conditions and may not be the same under extreme (heatwave) conditions.

Furthermore, differences between low- and high-emissions scenarios are more moderate than in cooling-dominant or mild climates, even by the 2070s, across both the seven GCMs and the CSIRO projected weather files.

Melbourne has higher variability across climate models compared to Canberra and Hobart, especially for cooling demand. The hottest model CESM2 produces between 122-248% increase in cooling demand under SSP1-2.6 and SSP3-7.0 respectively. There is a big range with the coldest model (NorESM2-MM) showing a small increase of 15% under SSP1-2.6. Overall, the balance heating and cooling changes lead to star ratings remaining stable or slightly increasing under future climates relative to the current NCC 2022 NatHERS star bands.

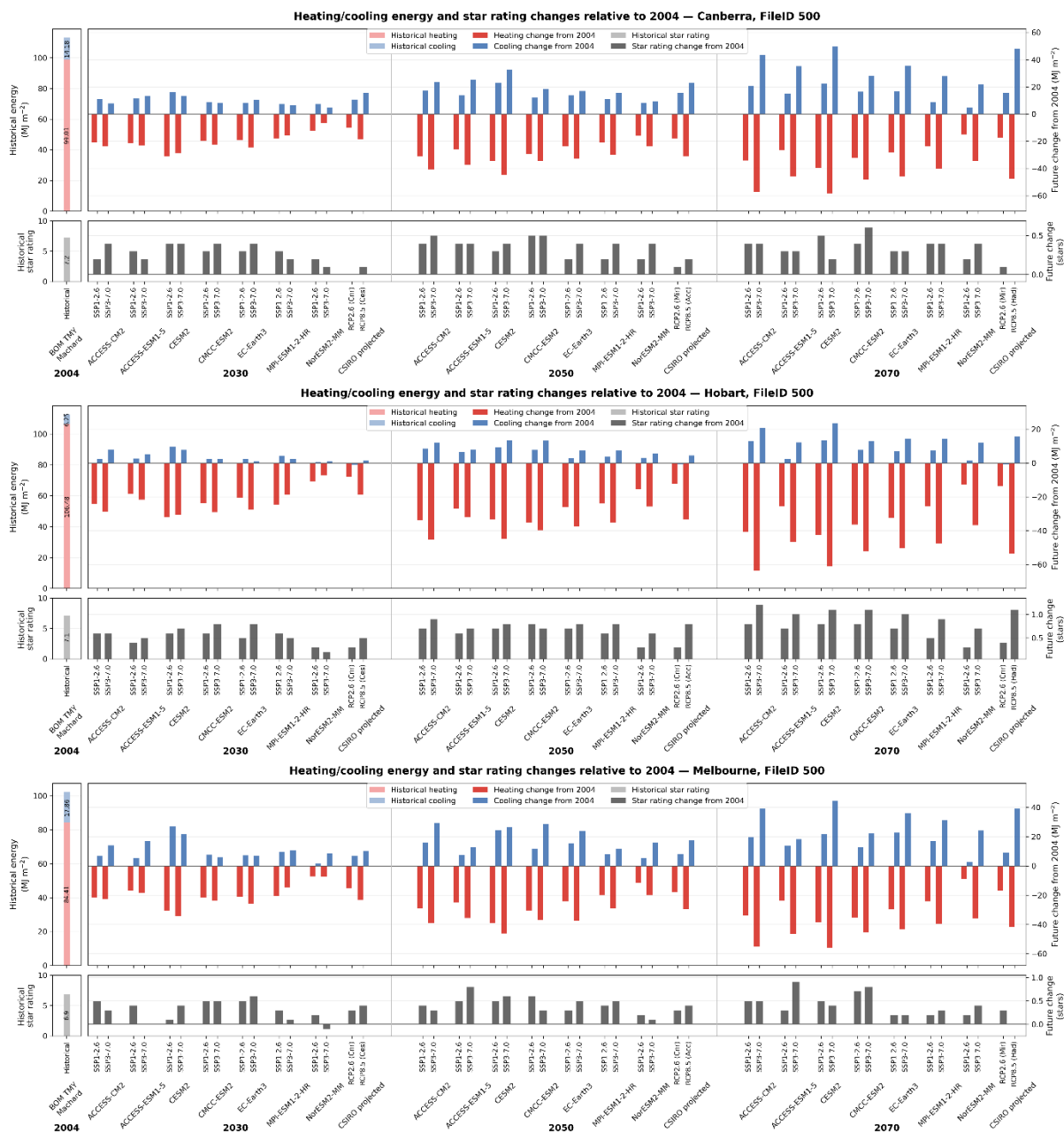


Figure 12: Comparing heating and cooling loads and star ratings for prototype future TMY files, both SSPs and all 7 climate models with historical TMY files and the CSIRO projected weather files for the 500 SAP standard NatHERS house type for presently heating-dominant Melbourne (Tullamarine), Victoria, Canberra CBD, ACT and Hobart CBD, Tasmania. Note the star ratings comparison in the future is relative to the current NCC 2022 NatHERS Star bands.

4.1.2 Case studies of application by industry practitioners /location specific examples

To test if the prototype files were fit-for-purpose, the building simulation practitioners (building designers and NatHERS assessors) also did case studies of different housing types in different locations with both TMY and XMY files.

Overall, the tests confirmed that the changes to heating and cooling demand differ notably depending on the SSP and climate model chosen. For more information (see Ren et al, in prep).

The addition of heatwave information (XMY) files also provided value to understanding predicted extreme heat in the future and the impacts on thermal conditions in homes. This allows understanding of potential implications for occupant health during these extreme conditions which has not been possible based on the current TMY files. Initial testing of the XMY files saw most testers choosing the severe XMY file from the hottest model and highest SSP, to 'stress test' the building design for peak energy efficiency and thermal comfort. Testing so far suggests that all 3 heatwave types (most severe, most intense and the longest) have value, depending on the decision being made. A comprehensive analysis of the prototype XMY files is currently underway (Strategy Policy Research and RED Sustainability, in prep).

5. Discussion

5.1 Evaluation of the methodology

Trying to incorporate future climate projections into weather files for building simulation has been a process of discovery. Through this process we worked through a number of challenges including:

- Applying the Quantile Delta Change (QDC) method for the first time in building simulation applications to transfer hourly, quantile-specific climate change signals from BARPA-R simulations onto the historical NatHERS data.
- Finding inconsistencies in both observations and future climate data that required additional processing and conversions.

The testing demonstrated that the prototype weather files are technically usable and suitable for residential thermal performance simulation. However, successful implementation would require supporting guidance to assist practitioners in selecting and applying the most appropriate future weather files for different decision-making contexts. In particular, guidance is needed to help users determine:

- which emissions scenario(s) (SSPs) should be applied;
- which climate model(s) should be selected;
- when a single file may be appropriate and when multiple files should be assessed;
- how TMY and XMY files should be used together; and
- how uncertainty across climate projections should be incorporated into building design decisions.

The project demonstrated the value of future weather files to inform climate-resilient building design but also highlighted that this cannot be treated as a one-off exercise. Future work will need to maintain and update files, document methods, support users, expand coverage and develop practical guidance. This could be achieved by a long-term national capability linking climate science, building simulation, software development, policy and industry practice. For more information about the detailed methodology and limitations refer to Hoffmann et al., 2026.

5.2 Implications for industry practice

The testing demonstrated that the prototype future weather files are technically suitable for use in residential building simulation. However, practical guidance on how to select, apply and interpret the large number of available files, the range of options across climate models, emissions pathways, time periods, locations and file types is needed.

The building simulation results using the full suite of future TMY files showed substantial variation across climate models, emissions pathways and future time periods. This indicates that the choice of global climate model and emissions scenario can materially affect predicted building thermal performance. In some cases, differences between climate models

translated into significant variations heating and cooling load, that would influence design decisions. For example, cooling loads for Sydney varied by up to 259% between models (under the same emissions scenario). Design responses that would achieve compliance could therefore vary widely depending on the choice of climate model, which introduces a risk of inappropriate outcomes when trying to improve future resilience. Variation between climate models therefore cannot be ignored, as it has practical implications for design decisions, compliance interpretation and future policy application. The project did not assess suitability of these files for regulatory use.

The future XMY files provide an additional capability by enabling practitioners to assess building performance under future heatwave conditions. These files should generally be used alongside future TMY files, rather than as substitutes for them. TMY files support assessment of performance under average future climate conditions, while XMY files enable stress-testing under extreme heat events. Used together, they provide a more complete basis for assessing both typical energy performance and resilience under conditions that are increasingly important for occupant health, cooling demand and peak electricity loads.

Modelling with XMY files can also potentially provide useful information for air-conditioning sizing, peak cooling demand and heat-stress mitigation. The simulation software tested was able to run the XMY files and generate hourly outputs from which design-relevant heatwave metrics could be derived. These outputs provide insight into how dwellings respond during heatwave events, including the timing and location of peak thermal stress within a building. For example, HERO reports peak energy demand in kWh for individual zones, alongside standard average energy demand outputs in MJ/m². This functionality can support design decisions, mitigation strategies and air-conditioning specification. However, not all software presents these outputs in the same way. In some tools, the relevant information is contained in raw hourly outputs and requires extraction and post-processing before it can be readily interpreted by practitioners.

For designers, assessors and building owners, the availability of future average and extreme weather files enables more informed decision-making and stress-testing of residential designs. The XMY files provide a capability that is not available through current NatHERS TMY weather files: a basis for assessing performance under future extreme heat. This is particularly important where the objective is to understand heat-stress performance, passive survivability, cooling system adequacy or the effectiveness of design responses such as shading, insulation, ventilation, glazing, zoning and orientation. There is therefore a clear practical case for heatwave-specific weather files if future thermal resilience is to be assessed.

At the same time, the use of XMY files introduces new interpretation challenges. The heatwave definition used to generate the files differs from the Bureau of Meteorology's Excess Heat Factor approach used for heatwave monitoring and forecasting in Australia. As a result, the heatwave characteristics represented in the XMY files are not directly comparable with some publicly reported heatwave projections. Further work may be needed to test whether alternative or additional heatwave definitions would improve comparability, communication and user confidence, particularly for policy, regulatory or public-facing

applications. In addition, humidity is a critical variable for thermal comfort and human health implications; more work is needed to accurately represent humidity in both observations and future climate projections.

Overall, the future weather files developed through this project could substantially improve the ability of industry to design homes for future climate conditions. However, they also introduce new decisions that practitioners are not currently required or equipped to make. To support application, industry will need clear guidance on which emissions scenarios, climate models, time periods and file types are appropriate for different assessment purposes. Guidance is also needed on how results should be interpreted when different climate models produce different performance outcomes. Without this supporting framework, the additional information provided by future TMY and XMY files will remain difficult to apply in routine practice, despite its clear value for climate-resilient building design.

5.4 Limitations and future work

The main limitation to this study is that we could only produce the prototype files in NatHERS-compatible format for residential applications. Building simulation practitioners expressed a need for future weather files in Energy Plus (.epw) formats for commercial applications, however they required additional information on future precipitation for hygrothermal considerations (e.g. mould/condensation risk) and commercial air-conditioning sizing. Intercomparisons of future climate projections across Australia have shown that unlike temperature trends, precipitation trends vary markedly across the projections, some regions show increases in precipitation whereas others show drying - overall, there is less confidence in these projections (Round et al. 2024, Narsey et al. 2025, Eccles et al. 2025). Therefore, more work would be needed to develop and test a methodology to attempt to represent future changes in precipitation in future weather files for building simulation for Australia, and extend the application to commercial buildings.

The prototype files are also subject to uncertainties in the historical reference data, regional climate projections and statistical-adjustment method. The XMYs should therefore be interpreted as plausible stress-test sequences rather than predictions of specific future events.

In addition, urban heat island effects are not represented in the current prototype files. The reason for this is two-fold, (i) the weather observations are often recorded some distance from the urban centres (e.g., airports) and (ii) the resolution of the climate projections (17km grid) doesn't resolve urban characteristics. However, this methodology is 'dataset agnostic', so as higher-resolution convection-permitting climate projections become more widely available, future work could incorporate these factors and further improve local climate representation, however, this may still be limited by the underpinning observations.

6. Conclusion

This study demonstrates that future average and extreme weather files can be generated in formats compatible with existing residential building simulation workflows, providing a practical pathway towards incorporating future climate risks into building design and assessment. The prototype files show that future warming is likely to increase cooling demand, reduce heating demand and substantially increase exposure to extreme heat, with implications that vary across Australian climate zones. Testing with building simulation practitioners confirmed that the files are technically fit for purpose and provide new capability for assessing both typical future performance and heatwave resilience. However, the wide range of possible future climates represented by different models, scenarios and time periods creates practical challenges for routine use and risks inappropriate outcomes. Further co-designed work is needed to develop practical guidance on file selection, use cases, interpretation and governance before any future policy or regulatory application. For more details, refer to the *Lessons Learnt report* for this project (Dalla Pozza et al, 2026). A long-term national capability linking climate science, building simulation, standards development and industry practice will be essential to ensure Australian homes are designed for the climate conditions they will experience over their lifetime.

The prototype files are available for testing for research purposes only see Guidance Note Appendix B DOI <https://doi.org/10.25914/s33s-kq39>

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Appendix A: Characteristics of Prototype files

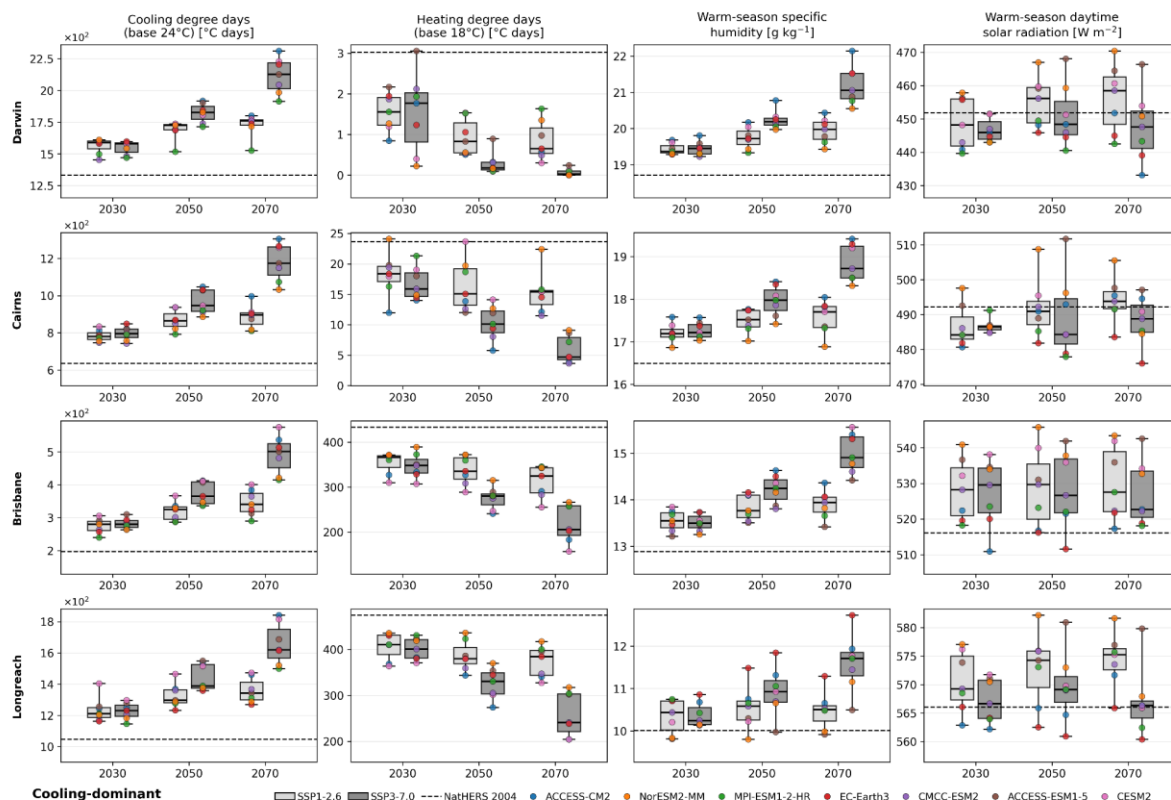


Figure A1: Climate characteristics of TMY files for cooling-dominant locations. From left to right: Cooling degree days with a comfort level of 24°C, heating degree days with a comfort level of 18°C, warm-season (October to March) specific humidity and warm-season daytime solar radiation (when solar radiation exceeds 10W/m²). Boxplots are paired for SSP1-2.6 and SSP3-7.0 for each future time period, with the thick black line representing the multi-model median, upper/lower box edges are the 25th/75th percentile ensemble range and whiskers show the hottest/coolest, most/least humid, and most/least sunny climate model. The horizontal dashed line represents conditions from NatHERS TMY files.

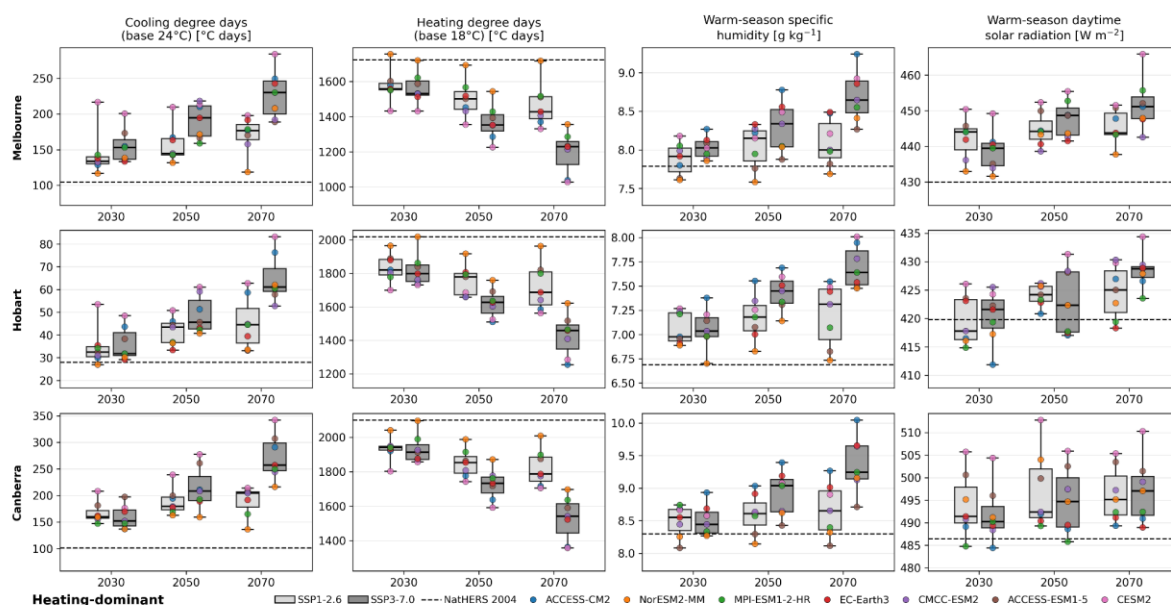


Figure A2: Same as Figure A1 but for heating-dominant locations.

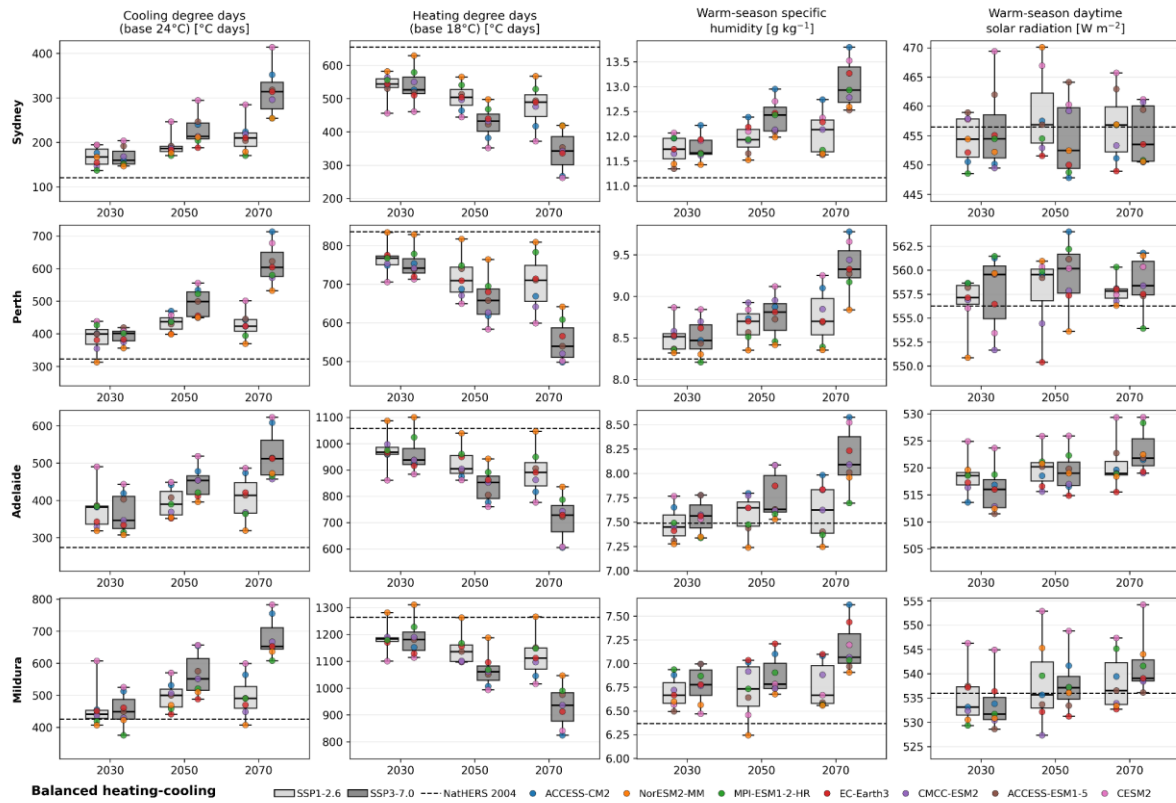


Figure A3: Same as Figure A1 but for balanced heating and cooling locations.

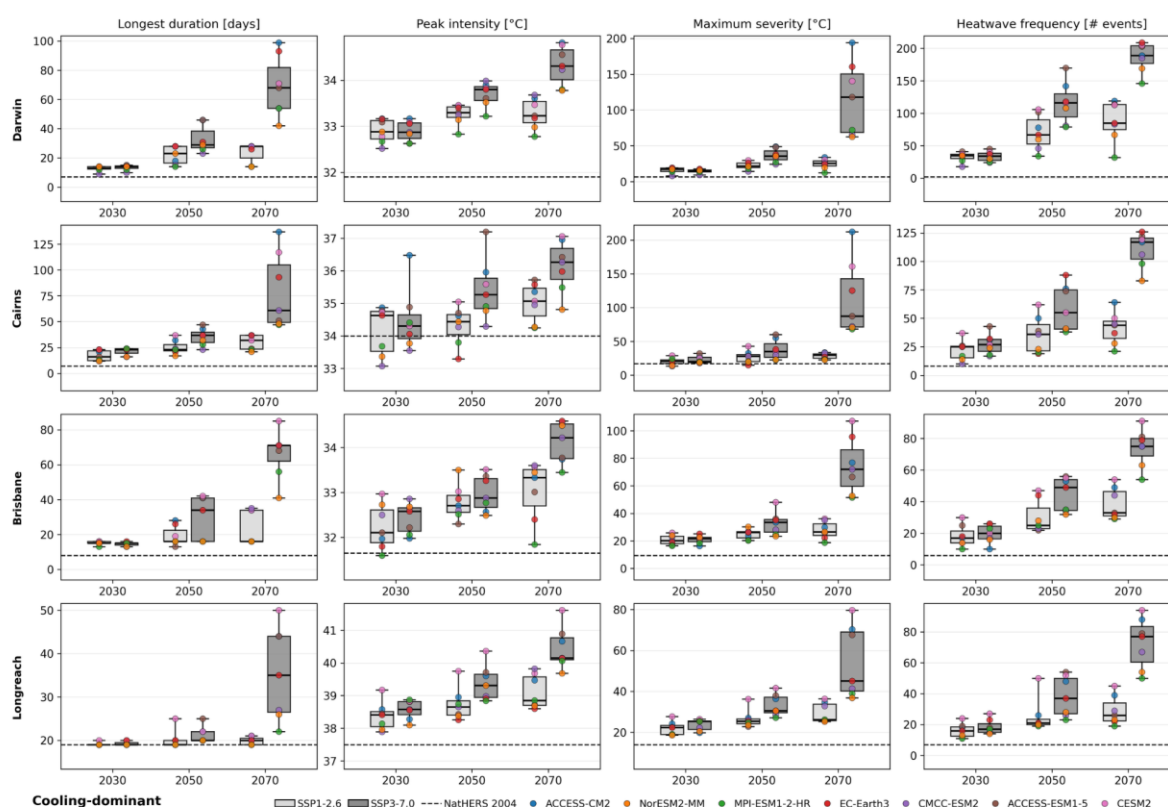


Figure A4: Climate characteristics of XMY files for cooling-dominant locations. From left to right: heatwave frequency in number of events, longest duration in days, peak intensity in °C and heatwave severity in °C. Note, heatwave frequency is calculated from the full 20-year climate simulation rather than the selected XMY weather file. The remaining metrics describe the heatwave represented within the selected XMY weather file. Boxplots are paired for SSP125 and SSP370 for each future time period, with the thick black line representing the multi-model median, upper/lower box edges are the 25th/75th percentile ensemble range and whiskers show the hottest/coolest, climate model. The horizontal dashed line represents conditions from NatHERS (historical) XMY files.

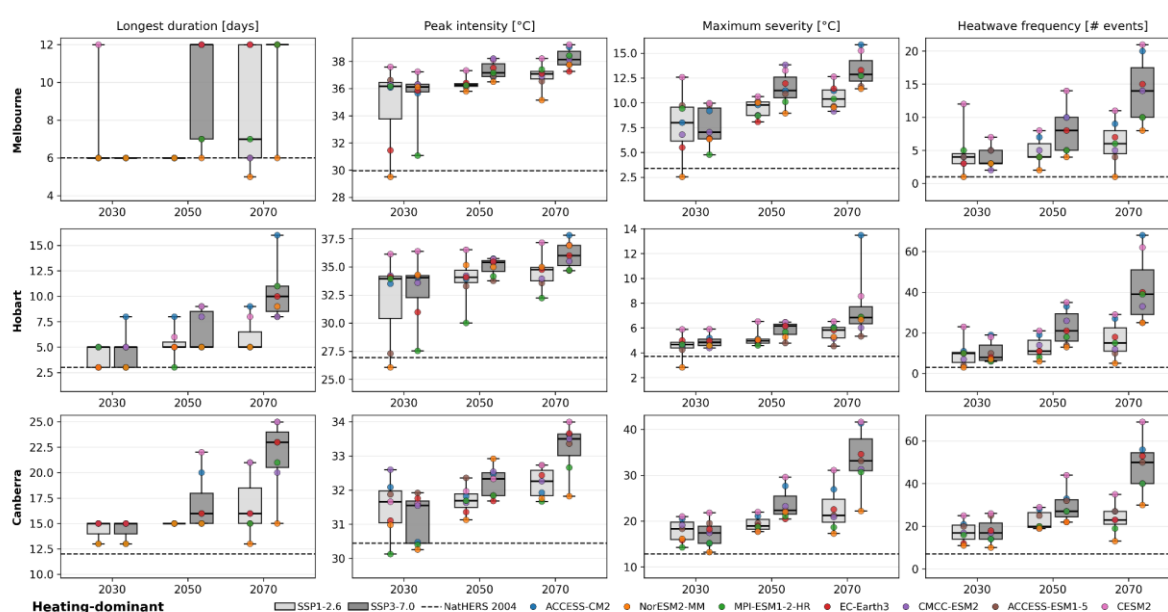


Figure A5: Same as Figure A4 but for heating-dominant locations.

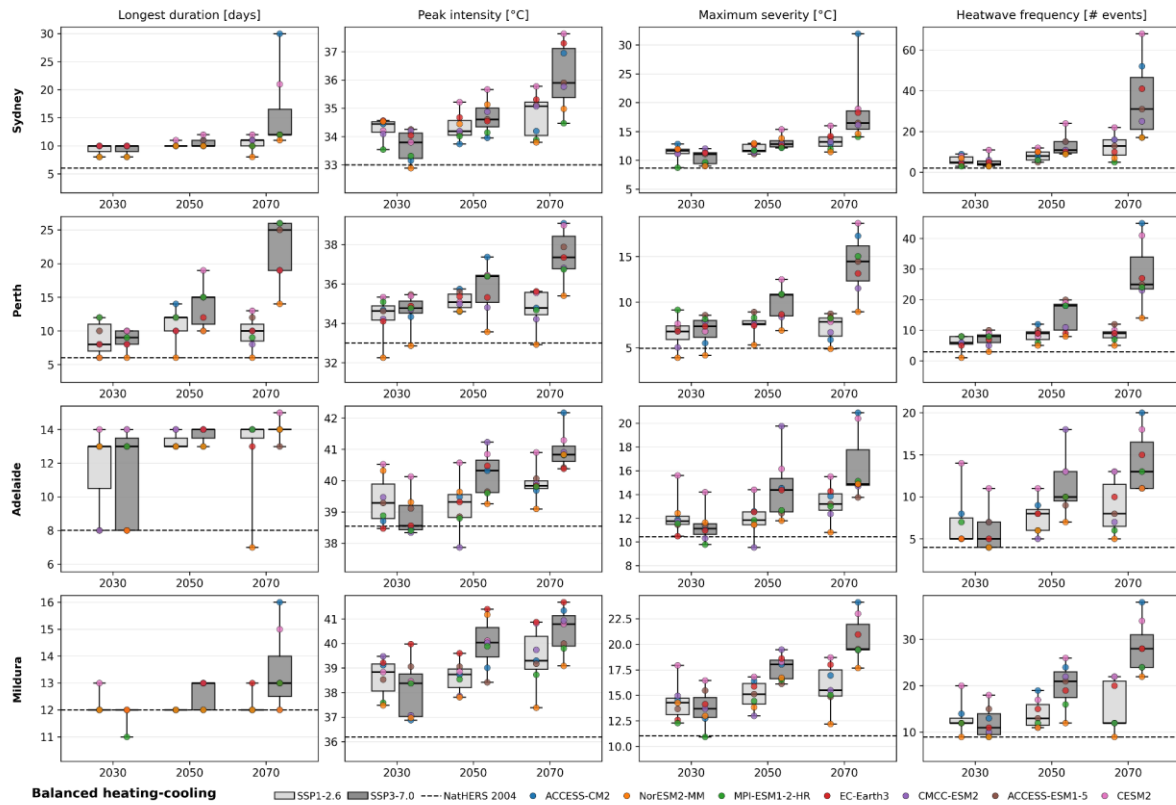


Figure A6: Same as Figure A4 but for balanced heating and cooling locations.

Appendix B: Guidance note for the Prototype files

Important: These files are prototype datasets generated for research, testing and feedback purposes only. They should not be used to inform building design, regulatory compliance, NatHERS assessments or operational energy efficiency assessments or to assess current regulations.

- The future weather files were produced as part of the Building for the Future research project under the National Environmental Science Program Climate Systems Hub.
- The objective of the prototype dataset is to explore the use of regional climate model projections to generate future climate weather files compatible with the NatHERS simulation framework.
- The prototype files support testing of workflows for generating NatHERS-compatible weather files from climate model simulations, bias-correction approaches suitable for building simulation variables, and potential future climate datasets for building performance modelling.
- These files are not approved NatHERS weather files and are not suitable for operational use. A more comprehensive process would be required before they could be considered for inclusion in any Australian Government policy or regulatory application.
- The prototype files will be accessible for research purposes on the National Computational Infrastructure Data Catalogue until March 2031.
- Access is open and free. There are no restrictions or controls on who can download the files.
- Metadata and the technical report will be provided. However, without future funding, there will be no resources from the NESP Climate Systems Hub project team, including Bureau of Meteorology staff, to support use of the files or further develop them.
- Testing showed that projected building performance can vary significantly depending on the climate model and emissions pathway selected. The choice matters.
- More testing and ongoing collaboration are needed to develop guidance on how this additional climate information should be used in practice and which aspects are most useful for informing design responses.

For more information



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