



Australia's National  
Science Agency

# Predictive weather files for building energy modelling

User Guide

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# 1 Introduction

This report describes the development of predictive weather files suitable for use by building energy simulation software. These files were created in response to growing demand for weather data suitable for exploring the impact of climate change on the built environment.

In 2020, Chen et al. developed predictive weather files suitable for use in non-regulatory residential building energy simulations which use Nationwide House Energy Rating Scheme (NatHERS) software. Projected changes under three future climate change scenarios were applied to Reference Meteorological Year (RMY) weather data. To make these files suitable for use by software such as EnergyPlus, ESP-r and IESVE some parameters were added, and the file was converted to the format (.epw) required by the software. Figure 1 gives an overview of the process used to create the predictive weather files.

Section 2 of this report describes the predictive weather datasets. Section 3 describes the CSIRO methodology for constructing predictive weather data. Section 4 describes the transformations necessary for converting the predictive weather files suitable for NatHERS software to the format and content required by software such as EnergyPlus, ESP-r, and IESVE (in .epw format).

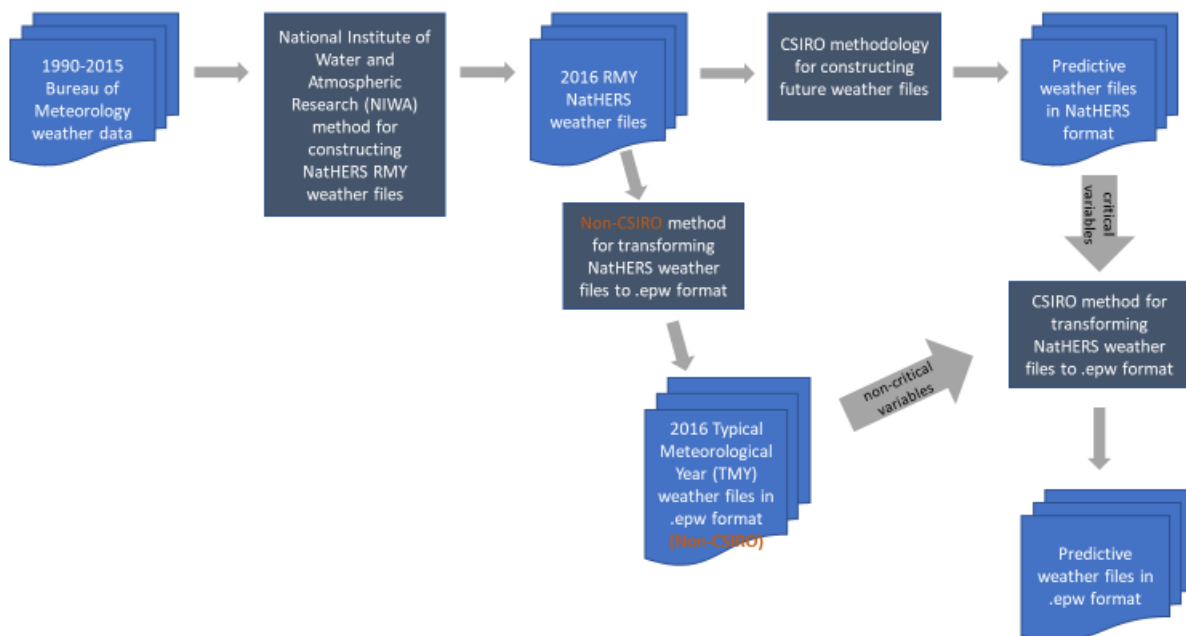


Figure 1 Overview of creation of weather files



## 2 The datasets

There are 2 predictive weather datasets: 'Predictive weather files in .epw format' and 'Predictive weather files in NatHERS format'. Each dataset consists of 996 text files in a single zip file. Each text file contains one year of weather data in hourly intervals.

Each text file contains hourly weather data for one of 83 Australian locations, under one of 3 future climate scenarios (RCP2.6, RCP4.5, or RCP8.5), for one of 4 future years (2030, 2050, 2070, or 2090).

The Representative Concentration Pathway (RCP) climate projections reflect a range of possible climate futures with varying levels of anthropogenic greenhouse gas (GHG) emissions, atmospheric GHG concentrations, and the resultant radiative forcing (Figure 2). In RCP2.6, atmospheric GHG emissions peak around 2020 then rapidly decline in line with strong emission reduction measures. In RCP4.5, GHG emissions peak in 2040, while RCP8.5 reflects a future with little curbing of GHG emissions.

The predictive weather data is based on a typical meteorological year of historical weather data drawn from the years 1990 to 2015. Global Climate Models and morphing were applied to this data to predict the future values under each climate scenario at each location.

The data is available in two text-based file formats:

- As .epw files that can be used by building simulation software such as EnergyPlus, ESP-r, and IESVE
- In a weather file format suitable for building simulations using NatHERS software such as AccuRate, BERSPro, FirstRate5, and HERO in **non-regulatory** mode. **Note that these files are NOT for use in a regulatory setting.**

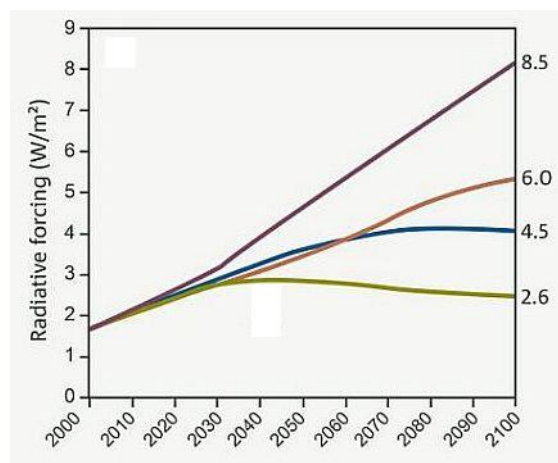


Figure 2 Resultant radiative forcing under different RCP scenarios. SOURCE: CSIRO and Bureau of Meteorology, Australia (2015)

## 2.1 Zip file structure

The text files in the zip file are arranged under the following directory hierarchy:

Location (83 locations)

Climate Scenario (RCP2.6, RCP4.5, & RCP8.5)

Future Year (2030, 2050, 2070, & 2090)

## 2.2 File naming

Each of the 996 files in the dataset has a unique name of the form:

*nn\_CZmmmm\_aa\_NH16\_bMY\_RCPrr\_yyyy.ccc*

For example:

60\_CZ0607\_TU\_NH16\_TMY\_RCP26\_2030.epw

Where:

*nn* = NatHERS climate zone

*mmmm* = Australian Climate Data Bank (ACDB) climate zone

*aa* = Location name code

*b* = 'T' (if .epw format) or 'R' (if NatHERS format)

*rr* = RCP number (without decimal point)

*yyyy* = future year

*ccc* = 'epw' (if .epw format) or 'txt' (if NatHERS format)

## 2.3 Locations

Predictive weather files exist for 83 locations around Australia (Table 1).

Table 1 Locations

NATHERS CLIMATE ZONE	ACDB CLIMATE ZONE	LOCATION NAME CODE	LOCATION NAME	POSTCODE	STATE	LONGITUDE	LATITUDE
1	CZ0101	DA	Darwin	800	NT	130.9	-12.4
2	CZ0110	HE	Pt Hedland	6721	WA	118.6	-20.4
3	CZ0304	LO	Longreach	4730	QLD	144.3	-23.4
4	CZ0307	CR	Carnarvon	6701	WA	113.7	-24.9
5	CZ0109	TO	Townsville	4810	QLD	146.8	-19.3
6	CZ0306	AL	Alice Springs	870	NT	133.9	-23.8
7	CZ0202	RO	Rockhampton	4700	QLD	150.5	-23.4
8	CZ0404	MO	Moree	2400	NSW	149.9	-29.5
9	CZ0206	AM	Amberley	4306	QLD	152.7	-27.6
10	CZ0205	BR	Brisbane	4000	QLD	153.1	-27.4
11	CZ0207	CH	Coffs Harbour	2450	NSW	153.1	-30.3

NATHERS CLIMATE ZONE	ACDB CLIMATE ZONE	LOCATION NAME CODE	LOCATION NAME	POSTCODE	STATE	LONGITUDE	LATITUDE
12	CZ0503	GE	Geraldton	6530	WA	114.7	-28.8
13	CZ0505	PE	Perth	6000	WA	115.9	-31.9
14	CZ0701	AA	Armidale (old Tamworth)	2350	NSW	151.7	-30.5
15	CZ0509	WE	Williamstown	2300	NSW	151.8	-32.8
16	CZ0514	AD	Adelaide	5000	SA	138.6	-34.9
17	CZ0512	SY	Sydney RO (Observatory Hill)	2000	NSW	151.2	-33.9
18	CZ0604	NO	Nowra	2541	NSW	150.5	-35
19	CZ0310	CV	Charleville	4470	QLD	146.3	-26.4
20	CZ0414	WA	Wagga	2650	NSW	147.5	-35.2
21	CZ0609	ME	Melbourne RO	3000	VIC	145	-37.8
22	CZ0612	SE	East Sale	3852	VIC	147.1	-38.1
23	CZ0707	LT	Launceston (Ti Tree Bend)	7250	TAS	147.1	-41.4
24	CZ0703	CA	Canberra	2600	ACT	149.2	-35.3
25	CZ0801	CM	Cabramurra (old Alpine)	2629	NSW	148.4	-35.9
26	CZ0709	HO	Hobart	7000	TAS	147.5	-42.8
27	CZ0413	MI	Mildura	3500	VIC	142.1	-34.2
28	CZ0602	RI	Richmond	2753	NSW	150.8	-33.6
29	CZ0102	WP	Weipa	4874	QLD	141.9	-12.7
30	CZ0104	WY	Wyndham	6740	WA	128.1	-15.5
31	CZ0105	WS	Willis Island	4871	QLD	150	-16.3
32	CZ0106	CN	Cairns	4870	QLD	145.8	-16.9
33	CZ0108	BM	Broome	6725	WA	122.2	-18
34	CZ0111	LM	Learmonth	6707	WA	114.1	-22.2
35	CZ0201	MK	Mackay	4740	QLD	149.2	-21.1
36	CZ0203	GL	Gladstone	4680	QLD	151.3	-23.9
37	CZ0301	HA	Halls Creek	6770	WA	127.7	-18.2
38	CZ0302	TE	Tennant Creek	860	NT	134.1	-19.6
39	CZ0303	IS	Mt Isa	4825	QLD	149.2	-21.1
40	CZ0305	NE	Newman	6753	WA	119.7	-23.4
41	CZ0401	GI	Giles	6438	WA	128.3	-25
42	CZ0402	MT	Meekatharra	6642	WA	118.5	-26.6
43	CZ0403	OO	Oodnadatta	5734	SA	135.5	-27.6
44	CZ0406	KA	Kalgoorlie	6430	WA	121.5	-30.8
45	CZ0408	WO	Woomera	5720	SA	136.8	-31.2
46	CZ0409	CO	Cobar	2835	NSW	145.8	-31.5
47	CZ0410	BI	Bickley	6076	WA	116.1	-32
48	CZ0411	DU	Dubbo	2830	NSW	148.6	-32.2

NATHERS CLIMATE ZONE	ACDB CLIMATE ZONE	LOCATION NAME CODE	LOCATION NAME	POSTCODE	STATE	LONGITUDE	LATITUDE
49	CZ0412	KT	Katanning	6317	WA	117.6	-33.7
50	CZ0501	OA	Oakey	4401	QLD	151.7	-27.4
51	CZ0504	FO	Forrest	6434	WA	128.1	-30.8
52	CZ0506	SW	Swanbourne	6010	WA	115.8	-32
53	CZ0507	CE	Ceduna	5690	SA	133.7	-32.1
54	CZ0508	MD	Mandurah	6210	WA	115.7	-32.5
55	CZ0510	EP	Esperance	6450	WA	121.9	-33.8
56	CZ0513	MA	Mascot (Sydney Airport)	2020	NSW	151.2	-33.9
57	CZ0603	MJ	Manjimup	6258	WA	116.1	-34.2
58	CZ0605	AB	Albany	6330	WA	117.8	-35
59	CZ0606	ML	Mt Lofty	5240	SA	138.7	-35
60	CZ0607	TU	Tullamarine (Melbourne Airport)	3020	VIC	144.9	-37.7
61	CZ0610	MG	Mt Gambier	5290	SA	140.8	-37.8
62	CZ0611	MR	Moorabbin	3189	VIC	145.1	-38
63	CZ0613	WR	Warrnambool	3280	VIC	142.4	-38.3
64	CZ0614	OT	Cape Otway	3220	VIC	143.5	-38.9
65	CZ0702	OR	Orange	2800	NSW	149.1	-33.4
66	CZ0705	BA	Ballarat	3350	VIC	143.8	-37.5
67	CZ0706	LD	Low Head	7253	TAS	146.8	-41.1
68	CZ0708	LU	Launceston Airport	7120	TAS	147.2	-41.5
69	CZ0802	TH	Thredbo (Village)	2625	NSW	148.3	-36.5
70	CZ0502	TW	Toowoomba	4350	QLD	151.9	-27.6
71	CZ0107	AT	Atherton	4880	QLD	145.5	-17.3
72	CZ0405	RX	Roxby Downs	5725	SA	136.9	-30.5
73	CZ0204	MN	Maleny	4552	QLD	152.9	-26.8
74	CZ0103	KN	Katherine	853	NT	132.3	-14.4
75	CZ0515	AC	Adelaide Coastal (AMO)	5950	SA	138.5	-35
76	CZ0407	TA	Tamworth	2340	NSW	150.8	-31.1
77	CZ0511	PA	Parramatta	2200	NSW	151	-33.8
78	CZ0704	SU	Sub-Alpine (Cooma Airport)	2630	NSW	149	-36.3
79	CZ0601	BL	Blue Mountains	2785	NSW	149	-21.5
80	CZ0608	CS	Coldstream	3770	VIC	145.4	-37.7
81	CZ0516	BU	Busselton	6280	WA	115.4	-33.7
82	CZ0208	GM	Glasshouse mountains	4519	QLD	153	-27
83	CZ0112	XI	Christmas Island	6798	WA	96.8	-12.2

## 2.4 EnergyPlus weather file (.epw) format

The EnergyPlus weather file format (.epw) is a text format with variable values separated by commas. The file structure is shown in Table 2. A sample of the data is shown in Figure 3.

The format is based on TMY2 which is a strict, position-specific format, with missing data filled with nines. SI units were used for all the data. Each weather file has basic (header) information followed by time step data.

The first eight lines provide basic information, including longitude, latitude, time zone, elevation, annual design conditions, monthly average ground temperatures, typical and extreme periods, holidays/daylight savings periods, and data periods.

The remaining lines provide time step data, including Dry Bulb Temperature, Dew Point Temperature, Relative Humidity, Atmospheric Station Pressure, Radiation (Extraterrestrial Horizontal, Extraterrestrial Direct Normal, Horizontal Infrared Radiation from Sky, Global Horizontal, Direct Normal, Diffuse Horizontal), Illuminance (Global Horizontal, Direct Normal, Diffuse Horizontal, Zenith), Wind (Direction, Speed), Sky Cover (Total, Opaque, Visibility, Ceiling Height), Present Weather (Observation, Codes), Precipitable Water, Aerosol Optical Depth, and Snow (Depth, Days Since Last Snowfall).

## 2.5 NatHERS weather file format

The NatHERS weather file has a position-specific text format. The file structure is shown in Figure 4. A sample of the data is shown in Figure 5

Weather data includes dry bulb temperature, absolute humidity, atmospheric pressure, wind (speed, direction), solar radiation (global, direct, diffuse), cloud cover, solar altitude, and solar azimuth.

Table 2 EnergyPlus (.epw) weather file format (adapted from Crawley, Lawrie and Hand, 1999)

LOCATION, A1 [City], A2 [State Province Region], A3 [Country], A4 [Data Source], N1 [WMO Number], N2 [Latitude {+N –S: -90.0 to +90.0: degrees minutes in decimal}], N3 [Longitude {-W +E: -180.0 to +180.0:degrees minutes in decimal}], N4 [Time Zone {-12.00 to +12.00: GMT-12 to GMT+12: partial hours in decimal}], N5 [Elevation {m: -1000.0 to +9999.9}],

DESIGN CONDITIONS, N1 [Annual Extreme Daily Mean Maximum Dry Bulb Temp {C}], N2 [Annual Extreme Daily Mean Minimum Dry Bulb Temp {C}], N3 [Annual Extreme Daily Standard Deviation Maximum Dry Bulb Temp {C}], N4 [Annual Extreme Daily Standard Deviation Minimum Dry Bulb Temp {C}], N5 [99.6% Heating Dry Bulb Temp {C}], N6 [99% Heating Dry Bulb Temp {C}], N7 [98% Heating Dry Bulb Temp {C}], N8 [0.4% Cooling Dry Bulb Temp {C}], N9 [0.4% Mean Coincident Wet Bulb Temp{C}], N10 [1.0% Cooling Dry Bulb Temp {C}], N11 [1.0% Mean Coincident Wet Bulb Temp {C}], N12 [2.0% Cooling Dry Bulb Temp {C}], N13 [2.0% Mean Coincident Wet Bulb Temp {C}], N14 [0.4% Cooling Dew Point Temp {C}], N15 [0.4% Mean Coincident Dry Bulb Temp {C}], N16 [0.4% Humidity Ratio {g/kg}], N17 [0.4% Relative Humidity], N18 [1.0% Cooling Dew Point Temp {C}], N19 [1.0% Mean Coincident Dry Bulb Temp {C}], N20 [1.0% Humidity Ratio {g/kg}], N21 [1.0% Relative Humidity], N22 [2.0% Cooling Dew Point Temp {C}], N23 [2.0% Mean Coincident Dry Bulb Temp {C}], N24 [2.0% Humidity Ratio {g/kg}], N25 [2.0% Relative Humidity], N26 [Daily Range of Dry Bulb Temp {C}], N27 [Heating Degree Days Base Temp {C}], N28 [Heating Degree Days], N29 [Cooling Degree Days Base Temp {C}], N30 [Cooling Degree Days]

TYPICAL/EXTREME PERIODS, N1 [Number of Typical/Extreme Periods], A1 [Typical/Extreme Period 1], A2 [Period 1 Start Day], A3 [Period 1 End Day], A4 [Typical/Extreme Period 2], A5 [Period 2 Start Day], A6 [Period 2 End Day], A7 [Typical/Extreme Period 3], A8 [Period 3 Start Day], A9 [Period 3 End Day], A10 [Typical/Extreme Period 4], A11 [Period 4 Start Day], A12 [Period 4 End Day], A13 [Typical/Extreme Period 5], A14 [Period 5 Start Day], A15 [Period 5 End Day], A16 [Typical/Extreme Period 6], A17 [Period 6 Start Day], A18 [Period 6 End Day], A19 [Typical/Extreme Period 7], A20 [Period 7 Start Day], A21 [Period 7 End Day], A22 [Typical/Extreme Period 8], A23 [Period 8 Start Day], A24 [Period 8 End Day]

GROUND TEMPERATURES, N1 [Number of Ground Temp Depths], N2 [Ground Temp Depth 1 {m}], N3 [Depth 1 Soil Conductivity {W/(mK)}], N4 [Depth 1 Soil Density {kg/m3}], N5 [Depth 1 Soil Specific Heat {kJ/(kgK)}], N6 [Depth 1 January Average Ground Temp {C}], N7 [Depth 1 February Average Ground Temp {C}], N8 [Depth 1 March Average Ground Temp {C}], N9 [Depth 1 April Average Ground Temp {C}], N10 [Depth 1 May Average Ground Temp {C}], N11 [Depth 1 June Average Ground Temp {C}], N12 [Depth 1 July Average Ground Temp {C}], N13 [Depth 1 August Average Ground Temp {C}], N14 [Depth 1 September Average Ground Temp {C}], N15 [Depth 1 October Average Ground Temp {C}], N16 [Depth 1 November Average Ground Temp {C}], N17 [Depth 1 December Average Ground Temp {C}], N18 [Ground Temp Depth 2{m}], N19 [Depth 2 Soil Conductivity {W/(mK)}], N20 [Depth 2 Soil Density {kg/m3}], N21 [Depth 2 Soil Specific Heat {kJ/(kgK)}], N22 [Depth 2 January Average Ground Temp {C}], N23 [Depth 2 February Average Ground Temp {C}], N24 [Depth 2 March Average Ground Temp {C}], N25 [Depth 2 April Average Ground Temp {C}], N26 [Depth 2 May Average Ground Temp {C}], N27 [Depth 2 June Average Ground Temp {C}], N28 [Depth 2 July Average Ground Temp {C}], N29 [Depth 2 August Average Ground Temp {C}], N30 [Depth 2 September Average Ground Temp {C}], N31 [Depth 2 October Average Ground Temp {C}], N32 [Depth 2 November Average Ground Temp {C}], N33 [Depth 2 December Average Ground Temp {C}], N34 [Ground Temp Depth 3 {m}], N35 [Depth 3 Soil Conductivity {W/(mK)}], N36 [Depth 3 Soil Density {kg/m3}], N37 [Depth 3 Soil Specific Heat {kJ/(kgK)}], N38 [Depth 3 January Average Ground Temp {C}], N39 [Depth 3 February Average Ground Temp {C}], N40 [Depth 3 March Average Ground Temp {C}], N41 [Depth 3 April Average Ground Temp {C}], N42 [Depth 3 May Average Ground Temp {C}], N43 [Depth 3 June Average Ground Temp {C}], N44 [Depth 3 July Average Ground Temp {C}], N45 [Depth 3 August Average Ground Temp {C}], N46 [Depth 3 September Average Ground Temp {C}], N47 [Depth 3 October Average Ground Temp {C}], N48 [Depth 3 November Average Ground Temp {C}], N49 [Depth 3 December Average Ground Temp {C}]

HOLIDAYS/DAYLIGHT SAVINGS, A1 [Day of Week], A2 [Daylight Savings Start Day], A3 [Daylight Savings End Day], N1 [Number of Holidays], A4 [Holiday 1 Name], A5 [Holiday 1 Day], ... , Ax [Holiday N Name], Ay [Holiday N Day]

COMMENTS1, A1 [Comments 1]

COMMENTS2, A1 [Comments 2]

DATA PERIODS, N1 [Number of Data Periods], A1 [Data Period 1 Name/Description], A2 [Data Period 1 Start Day], A3 [Data Period 1 End Day], A4 [Data Period 2 Name/Description], A5 [Data Period 2 Start Day], A6 [Data Period 2 End Day], A7 [Data Period 3 Name/Description], A8 [Data Period 3 Start Day], A9 [Data Period 3 End Day], A10 [Data Period 4 Name/Description], A11 [Data Period 4 Start Day], A12 [Data Period 4 End Day], A13 [Data Period 5 Name/Description], A14 [Data Period 5 Start Day], A15 [Data Period 5 End Day], A16 [Data Period 6 Name/Description], A17 [Data Period 6 Start Day], A18 [Data Period 6 End Day], A19 [Data Period 7 Name/Description], A20 [Data Period 7 Start Day], A21 [Data Period 7 End Day], A22 [Data Period 8 Name/Description], A23 [Data Period 8 Start Day], A24 [Data Period 8 End Day], A25 [Data Period 9 Name/Description], A26 [Data Period 9 Start Day], A27 [Data Period 9 End Day], A28 [Data Period 10 Name/Description], A29 [Data Period 10 Start Day], A30 [Data Period 10 End Day], A31 [Data Period 11 Name/Description], A32 [Data Period 11 Start Day], A33 [Data Period 11 End Day], A34 [Data Period 12 Name/Description], A35 [Data Period 12 Start Day], A36 [Data Period 12 End Day]

N1 [Year], N2 [Month {1-12}], N3 [Day {1-31}], N4 [Hour {0-23}], N5 [Minute {0-59}], A1 [Data Source and Uncertainty Flags], N6 [Dry Bulb Temp {C}], N7 [Dew Point Temp {C}], N8 [Relative Humidity {0.0 to 1.0}], N9 [Atmospheric Station Pressure {mb}], N10 [Extraterrestrial Horizontal Radiation {Wh/m<sup>2</sup>}], N11 [Extraterrestrial Direct Normal Radiation {Wh/m<sup>2</sup>}], N12 [Horizontal Infrared Radiation from Sky {Wh/m<sup>2</sup>}], N13 [Global Horizontal Radiation {Wh/m<sup>2</sup>}], N14 [Direct Normal Radiation {Wh/m<sup>2</sup>}], N15 [Diffuse Horizontal Radiation {Wh/m<sup>2</sup>}], N16 [Global Horizontal Illuminance {lux}], N17 [Direct Normal Illuminance {lux}], N18 [Diffuse Horizontal Illuminance {lux}], N19 [Zenith Luminance {Cd/m<sup>2</sup>}], N20 [Wind Direction {degrees}], N21 [Wind Speed {m/s}], N22 [Total Sky Cover], N23 [Opaque Sky Cover], N24 [Visibility {km}], N25 [Ceiling Height {m}], N26 [Present Weather Observation], A2 [Present Weather Codes], N27 [Precipitable Water {mm}], N28 [Aerosol Optical Depth {thousandths}], N29 [Snow Depth {cm}], N30 [Days Since Last Snowfall]

LOCATION,Mascot (Sydney AP),NSW,Australia,NatHERS-TMY2 BoM 66037 CZ0513,947670,-33.94,151.17,10.0,5  
DESIGN CONDITIONS,0  
TYPICAL/EXTREME PERIODS,0  
GROUND TEMPERATURES,0  
HOLIDAYS/DAYLIGHT SAVING,No,0,0,0  
COMMENTS 1,TMY2 months selected from 1990- 2016 out of 26 years of data; after Marion & Urban (1995), US National Renewable Energy Lab, NREL/SP-463-7668. Data reliability GOOD.  
COMMENTS 2,Weights: T\_dry 0.20, T\_dew 0.20, Wind 0.10, R\_glob 0.25, R\_dir 0.25. Details in NIWA Client report 2019175WN, Ben Liley <Ben.Liley@niwa.co.nz>, Apr 2020.  
DATA PERIODS,1,1,TMY2 Year,Sunday,1/1,12/31  
2070,01,01,01,60,E8E8E8E8?0?3?3?3?3I4I4I6I5B8B8E8E8?0?0E8?0?0?0,20.7,12.5,59,101800,0,1407,9999,0,0,0,0,0,0,0,315,2.4,1,99,9999,99999,9,999999999,23,0,999,99,99  
2070,01,01,02,60,A7A7A7A7?0?3?3?3?3I4I4I6I5A7A7E8E8?0?0A7?0?0?0,20.8,12.4,58,101600,0,1407,9999,0,0,0,0,0,0,0,337,2.5,1,99,9999,99999,9,999999999,23,0,999,99,99  
2070,01,01,03,60,A7A7A7A7?0?3?3?3?3I4I4I6I5A7A7E8E8?0?0A7?0?0?0,20.9,12.4,58,101600,0,1407,9999,0,0,0,0,0,0,0,337,2.9,1,99,9999,99999,9,999999999,23,0,999,99,99  
2070,01,01,04,60,A7A7A7A7?0?3?3?3?3I4I4I6I5A7A7A7?0?0A7?0?0?0,20.3,12.3,59,101600,0,1407,9999,0,0,0,0,0,0,0,337,2.9,1,99,9999,99999,9,999999999,22,0,999,99,99  
2070,01,01,05,60,A7A7A7A7?0?3?3?3?3I4I4I6I5A7A7A7?0?0A7?0?0?0,19.0,12.2,64,101600,0,1407,9999,0,0,0,0,0,0,0,315,2.4,1,99,9999,99999,9,999999999,23,0,999,99,99  
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2070,01,02,03,60,A7A7A7A7?0?3?3?3?3I4I4I6I5A7A7A7?0?0A7?0?0?0,21.9,15.6,67,101600,0,1407,9999,0,0,0,0,0,0,0,337,1.8,1,99,9999,99999,9,999999999,28,0,999,99,99  
2070,01,02,04,60,A7A7A7A7?0?3?3?3?3I4I4I6I5A7A7A7?0?0A7?0?0?0,21.9,15.3,65,101600,0,1407,9999,0,0,0,0,0,0,0,360,1.3,1,99,9999,99999,9,999999999,28,0,999,99,99  
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2070,01,02,08,60,A7A7A7A7?0A3A3D3I4I4I6I5A7A7A7?0?0A7?0?0?0,23.8,15.0,57,101800,569,1407,9999,396,849,52,56934,90188,7128,119,337,2.4,1,99,9999,99999,9,999999999,26,0,999,99,99  
2070,01,02,09,60,A7A7A7A7?0A3A3D3I4I4I6I5A7A7A7?0?0A7?0?0?0,25.4,14.2,49,101800,829,1407,9999,632,994,45,79744,99804,8701,1,62,360,4.8,1,99,9999,99999,9,999999999,24,0,999,99,99  
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2070,01,02,12,60,A7A7A7A7?0A3A3D3I4I4I6I5A7A7A7?0?0A7?0?0?0,28.3,10.5,32,101800,1340,1407,9999,1077,1041,85,114034,102750,12317,605,22,8.2,1,99,9999,99999,9,999999999,20,0,999,99,99  
2070,01,02,13,60,A7A7A7A7?0A3A3D3I4I4I6I5A7A7A7?0?0A7?0?0?0,29.3,10.3,30,101700,1381,1407,9999,1104,1020,102,114414,103691,11487,763,22,7.9,0,99,9999,99999,9,999999999,22,0,999,99,99  
2070,01,02,14,60,A7A7A7A7?0A3A3D3I4I4I6I5A7A7A7?0?0A7?0?0?0,29.9,11.3,31,101700,1348,1407,9999,1081,1043,80,108524,103569,11195,585,45,8.8,1,99,9999,99999,9,999999999,23,0,999,99,99

Figure 3 Sample of .epwformat data



DATA FORMAT FOR AUSTRALIAN CLIMATIC DATA BASE

Characters

Item

- 1 - 2 location identification (e.g. ME represents Melbourne)
- 3 - 4 year (e.g. 67)
- 5 - 6 month (i.e. 1 - 12)
- 7 - 8 day (i.e. 1 - 31)
- 9 - 10 hour standard (i.e. 0-23, 0 = midnight)
- 11 - 14 dry bulb temperature (10-1 °C)
- 15 - 17 absolute moisture content (10-1 g/kg)
- 18 - 21 atmospheric pressure (10-1 kPa)
- 22 - 24 wind speed (10-1 m/s)
- 25 - 26 wind direction (0-16; 0 = CALM. 1 = NNE , ..., 16 = N)
- 27 total cloud cover (oktas, 0 - 8)
- 28 flag relating to dry bulb temperature
- 29 flag relating to absolute moisture content
- 30 flag relating to atmospheric pressure
- 31 flag relating to wind speed and direction
- 32 flag relating to total cloud cover
- 33 blank
- 34 - 37 global solar irradiance on a horizontal plane (W/m2)
- 38 - 40 diffuse solar irradiance on a horizontal plane (W/m2)
- 41 - 44 direct solar irradiance on a plane normal to the beam (W/m2)
- 45 - 46 solar altitude (degrees, 0-90)
- 47 - 49 solar azimuth (degrees, 0-360)
- 50 flag relating to global and diffuse solar irradiance
- 51 flag }
- 52 - 56 Australian Met Station Number } Some locations only
- 57 - 61 wet bulb temperature (10-1 °C) }
- 62 - 81 Station name (first line only) }

Values for flags relating to standard surface meteorological data (columns 28 - 32)

- 0 means that the value is measured value
- 1 means that the value is estimated to replace a missing measurement
- 2 means that the value is an interpolating between three-hourly measurements
- 3 missing value

Values for flag relating to solar radiation data (column 50)

- 0 means that both global and diffuse irradiance values are based on measurements
- 1 means that both global and diffuse irradiance values are estimated to replace a missing measurement
- 2 means that the global irradiance value is based on measurement but the diffuse irradiance value is estimated to replace a missing measurement
- 3 missing value or estimated value from cloud cover data
- 4 interpolated value from three hourly data

Figure 4 NatHERS weather file structure

MA120101	0	207	951018	24141000010	0	0	0	018131320
MA120101	1	208	951016	25151111210	0	0	0	016531320
MA120101	2	209	951016	29151000010	0	0	0	015031320
MA120101	3	203	941016	29151000010	0	0	0	013731320
MA120101	4	190	931016	24141000000	0	0	0	012731320
MA120101	5	192	951016	24161000000	5	5	4	111800020
MA120101	6	196	951017	29151000000	176	42	6371211000020	
MA120101	7	210	951017	29141000000	416	37	9332410300020	
MA120101	8	234	871017	55161000000	655	32105636	9500020	
MA120101	9	251	871017	34160000000	862	42110649	8700020	
MA12010110	265	871017	401600000001007	49109861	7600020			
MA12010111	270	871016	40	210000001104	61109372	5600020		
MA12010112	279	861016	58	200000001135	72108179	400020		
MA12010113	284	861015	79	200000001107	5910947330700020			
MA12010114	290	881015	82	200000001011	4910976228500020			
MA12010115	284	841014	79	20000000	862	4210925027400020		
MA12010116	283	921014	82	20000000	664	3310563826600020		
MA12010117	279	921014	79	21000000	426	31	9272525800020	
MA12010118	266	971015	74	23000000	172	49	5351325100020	
MA12010119	2561041016	64	27000000	0	0	0	224300020	
MA12010120	2491071016	69	11000000	0	0	0	023400020	
MA12010121	2431101017	45	21000000	0	0	0	022431320	
MA12010122	2421131017	45	22000000	0	0	0	021231320	
MA12010123	2331161017	45	22000000	0	0	0	019731320	
MA120102	0	2311171017	24	22000000	0	0	0	018131320
MA120102	1	2301191016	24	11000000	0	0	0	016531320
MA120102	2	2191171016	18151001000	0	0	0	015031320	
MA120102	3	2191151016	13161000000	0	0	0	013731320	
MA120102	4	2091151016	21141000000	0	0	0	012731320	
MA120102	5	2091141017	24141000000	4	4	1	111800020	
MA120102	6	2171131017	21151000000	162	52	5311211000020		
MA120102	7	2381131018	24151000000	396	52	8492410300020		
MA120102	8	2541081018	48161000000	632	45	99436	9500020	
MA120102	9	265	981018	55	11000000	834	50104549	8700020
MA12010210	279	931018	79	21000000	985	65105261	7600020	
MA12010211	283	851018	82	120000001077	85104172	5600020		
MA12010212	293	851017	79	100000001104102102079	400020			
MA12010213	299	911017	88	200000001081	8010437330800020			
MA12010214	296	961016	98	21000000	994	5510596228600020		
MA12010215	2931001016	98	20000000	845	4110495027400020			
MA12010216	2841031015	93	20000000	641	36	9913826600020		
MA12010217	2781111015	98	21000000	401	50	8212525800020		
MA12010218	2771171015	98	24000000	157	62	4171325100020		
MA12010219	2651161016109	27000000	0	0	0	224300020		
MA12010220	2591181016	88	11000000	0	0	0	023500020	
MA12010221	2541171017	82	11000000	0	0	0	022431320	
MA12010222	2521171017	79	11000010	0	0	0	021231320	

Figure 5 Sample of NatHERS weather file data

### 3 CSIRO methodology for constructing future weather data

The dataset ‘Predictive weather files in NatHERS format’ is based on the dataset ‘NatHERS 2016 Reference Meteorological Year (RMY) weather files’. Predicted changes in critical weather variables due to climate change have been applied to the RMY files (Chen et al. 2020).

The ‘NatHERS 2016 RMY weather files’ contain hourly weather data for a typical meteorological year in 83 Australian locations. The typical meteorological year is drawn from historical weather data from 1990 to 2015 using the method described by the New Zealand National Institute of Water and Atmospheric Research (NIWA 2017).

Future weather predictions were made under 3 different GHG emission scenarios (RCP2.6, RCP4.5, and RCP8.5) as defined under the Climate Futures Framework (<https://www.climatechangeinaustralia.gov.au/en/>). The 3 selected Representative Concentration Pathways (RCP) reflect varying levels of anthropogenic GHG emissions, atmospheric GHG concentrations, and the resultant radiative forcing (in W/m<sup>2</sup>) (Figure 2) for the period from 2020 to 2100. In RCP2.6, atmospheric GHG emissions peak around 2020, then rapidly decline in line with strong emission reduction measures. In RCP4.5, GHG emissions peak in 2040, while RCP8.5 reflects a future with little curbing of GHG emissions. Further RCP details are described by van Vuuren et al. (2011).

Eight General Circulation Models (GCMs) were used to predict the monthly mean changes in critical weather variables under each of the 3 GHG emission scenarios at each of the 80 locations. The 8 GCMs selected are based on the Coupled Model Intercomparison Project 5 (CMIP5). Table 3 describes their main characteristics. Selection of the GCMs took into account their capability and accuracy in predicting the critical weather variables required for building energy simulations.

**Table 3 Characteristics of the selected eight Global Climate Models**

SELECTED MODELS	INSTITUTE	CHARACTERISTICS
ACCESS1.0	CSIRO-BOM, Australia	Maximum consensus for many regions.
CESM1-CAM5	CCCMA, Canada	Hotter and wetter, or hotter and least drying
CNRM-CM5	NSF-DOE-NCAR, USA	Hot /wetter end of range in Southern Australia
GFDL-ESM2M	CNRM-CERFACS, France	Hotter and drier model for many clusters
HadGEM2-CC	NOAA, GFDL, USA	Maximum consensus for many regions.
CanESM2	MOHC, UK	the hot/wetter mode
MIROC5	JAMSTEC, Japan	Low warming wetter model
NorESM1-M	NCC, Norway	Low warming wettest representative model

Predicted monthly mean changes in critical weather variables were applied to the hourly data in the ‘NatHERS 2016 RMY weather files’ using the ‘morphing’ methodology developed by Belcher et al. (2006). For building energy simulations, the critical weather variables are ambient dry-bulb air

temperature, relative humidity, solar radiation (global, direct and diffuse), and wind speed. Predicted hourly values were estimated using equations 1-5 below.

### Ambient dry-bulb air temperature

$$T = T_0 + \Delta T_m + \alpha_{Tm} (T_0 - \langle T_0 \rangle_m) \quad (1)$$

$$\alpha_{Tm} = \frac{\Delta T_{MAX_m} - \Delta T_{MIN_m}}{\langle T_{0max} \rangle_m - \langle T_{0min} \rangle_m} \quad (2)$$

Where:

- $T$  is the ambient dry-bulb temperature at a particular date and hour in a future year that we wish to calculate (e.g. temperature at 8:00 am 2<sup>nd</sup> January 2030)
- $T_0$  is the ambient dry-bulb temperature at the same date and hour in the baseline weather data (e.g. temperature at 8:00 am 2<sup>nd</sup> January in the 'NatHERS 2016 RMY weather files')
- $\Delta T_m$  is the change in mean ambient dry-bulb temperature for this month as projected by the GCMs (e.g. the difference between the mean temperature for January 2030 and the mean temperature for January in the 'NatHERS 2016 RMY weather files')
- $\langle T_0 \rangle_m$  is the mean ambient dry-bulb temperature for the month in the baseline weather data (e.g. mean temperature for January in 'NatHERS 2016 RMY weather files')
- $\Delta T_{MAX_m}$  is the change in mean maximum ambient dry-bulb temperature for the month as projected by the GCMs
- $\Delta T_{MIN_m}$  is the change in mean minimum ambient dry-bulb temperature for the month as projected by the GCMs
- $\langle T_{0max} \rangle_m$  is the monthly mean value of daily maximum ambient dry-bulb temperature from the baseline weather data
- $\langle T_{0min} \rangle_m$  is the monthly mean value of daily minimum ambient dry-bulb temperature from the baseline weather data

### Relative humidity

$$RH = RH_0(1 + \alpha_{Hm}) \quad (3)$$

Where:

- $RH$  is the relative humidity at a particular date and hour in a future year that we wish to calculate (e.g. 8:00 am 2<sup>nd</sup> January 2030)
- $RH_0$  is the relative humidity at the same date and hour in the baseline weather data (e.g. 8:00 am 2<sup>nd</sup> January in the 'NatHERS 2016 RMY weather files')
- $\alpha_{Hm}$  is the fractional monthly mean change of relative humidity as projected by the GCMs

### Wind Speed

$$U = U_0(1 + \alpha_{Um}) \quad (4)$$

Where:

- $U$  is the wind speed at a particular date and hour in a future year that we wish to calculate
- $U_0$  is the wind speed at the same date and hour in the baseline weather data

- $\alpha_{Um}$  is the fractional monthly mean change of wind speed as projected by the GCMs

### Solar Radiation

$$I = I_0(1 + I_{Rm}) \quad (5)$$

Where:

- $I$  is the solar radiation at a particular date and hour in a future year that we wish to calculate
- $I_0$  is the solar radiation at the same date and hour in the baseline weather data
- $\alpha_{Rm}$  is the fractional monthly mean change of solar radiation as projected by the GCMs

### Note

The 'NatHERS 2016 RMY weather files' (used as the starting point for constructing future weather data) contain the variable Absolute Moisture Content instead of Relative Humidity. Relative Humidity was derived from the variables Atmospheric Pressure, Dry Bulb Temperature, and Absolute Moisture Content using Equations 6-10 (see section 4). Predicted future values for Relative Humidity were then calculated as described above. Future values for Absolute Moisture Content were then derived from the future values of Relative Humidity and Dry Bulb Temperature together with the (unchanged) Atmospheric Pressure according to the same equations, but in reverse.

## 4 CSIRO methodology for converting weather files in NatHERS format to .epw format

The EnergyPlus (.epw) format requires some variables that are not contained in the NatHERS format. The critical variables are derived from variables contained within the NatHERS format. Other values are filled with values from a version of the 2016 TMY weather files created by a third party.

Relative Humidity and Dew Point Temperature are calculated using the NatHERS variables Dry Bulb Temperature, Absolute Humidity, and Atmospheric Pressure as described in Equations 6-10 (Snyder 2005, Buck 1981).

$$RH = \frac{P_v}{P_s} \times 100 \quad (6)$$

$$P_v = \frac{AH \times (T + 273.16)}{2165} \quad (7)$$

$$P_s = (1.0007 + 3.46 \times P \times 10^{-6}) \times 6.1121 \times e^{17.502T/(240.97+T)} \quad (8)$$

$$T_d = \frac{237.3 \times b}{1 - b} \quad (9)$$

$$b = \frac{\ln\left(\frac{RH}{100}\right)}{17.27} + \frac{T}{237.3 + T} \quad (10)$$

Where:

- $RH$  is the relative humidity (%)
- $P_v$  is the vapour pressure of the air (mbar)
- $P_s$  is the saturation vapour pressure of the air (mbar)
- $AH$  is the absolute humidity ( $\text{g}/\text{m}^3$ )
- $T$  is the dry-bulb temperature of the air ( $^{\circ}\text{C}$ )
- $P$  is the absolute pressure of the air (mbar)
- $T_d$  is the dew point temperature ( $^{\circ}\text{C}$ )

Some variables have different units and conversion is necessary to account for this (e.g. conversion from kPa to mb for Atmospheric Pressure).

Table 4 summarises the origin of each variable value in the EnergyPlus (.epw) format.

**Table 4 Origin of weather variables in .epw files**

ENERGYPLUS (.EPW) VARIABLE	ORIGIN
Dry Bulb Temp	NatHERS Dry bulb temperature with change of unit
Dew Point Temp	Calculated using NatHERS Dry Bulb Temperature, Absolute Moisture Content, and Atmospheric Pressure (Eq 6-10)
Relative Humidity	Calculated using NatHERS Dry Bulb Temperature, Absolute Moisture Content, and Atmospheric Pressure (Eq 6-8)
Atmospheric Station Pressure	NatHERS Atmospheric pressure with change of unit
Extraterrestrial Horizontal Radiation	As per 2016 Non-CSIRO TMY
Extraterrestrial Direct Normal Radiation	As per 2016 Non-CSIRO TMY
Horizontal Infrared Radiation from Sky	As per 2016 Non-CSIRO TMY
Global Horizontal Radiation	NatHERS Global solar irradiance on a horizontal plane
Direct Normal Radiation	NatHERS Direct solar irradiance on a plane normal to the beam
Diffuse Horizontal Radiation	NatHERS Diffuse solar irradiance on a horizontal plane
Global Horizontal Illuminance	As per 2016 Non-CSIRO TMY
Direct Normal Illuminance	As per 2016 Non-CSIRO TMY
Diffuse Horizontal Illuminance	As per 2016 Non-CSIRO TMY
Zenith Luminance	As per 2016 Non-CSIRO TMY
Wind Direction	2016 RMY NatHERS Wind direction with change of unit
Wind Speed	NatHERS Wind speed with change of unit
Total Sky Cover	As per 2016 Non-CSIRO TMY
Opaque Sky Cover	As per 2016 Non-CSIRO TMY
Visibility	As per 2016 Non-CSIRO TMY
Ceiling Height	As per 2016 Non-CSIRO TMY
Present Weather Observation	As per 2016 Non-CSIRO TMY
Present Weather Codes	As per 2016 Non-CSIRO TMY
Precipitable Water	As per 2016 Non-CSIRO TMY
Aerosol Optical Depth	As per 2016 Non-CSIRO TMY
Snow Depth	As per 2016 Non-CSIRO TMY
Days Since Last Snowfall	As per 2016 Non-CSIRO TMY

## 5 QA and feedback process

### 5.1 QA process

The predictive weather files were converted to the .epw format using the methodology described in this user guide by the CSIRO, who then reviewed the files and found that they worked on EnergyPlus.

All predictive weather files were then provided to an independent consultant with access to IES-VE who reviewed them. The consultant found that the files were usable in IES-VE and identified errors. The errors found were:

- External relative humidity over 100%
- Incorrect wet bulb temperature
- Incorrect dewpoint temperature
- Incorrect absolute humidity

The CSIRO addressed these errors by:

1. Replacing negative values with the data derived from the two hours before and after these three points using a linear approach
2. Replacing estimated relative humidity greater than 100% with 100%
3. Replacing estimated relative humidity less than 1% with 1% for .epw files
4. Leaving dew point temperature found to be less than -30°C as it was, since there was no reliable data on which to base modification.

The independent consultant re-checked a sample of five representative files and found that the errors in the sample had been corrected and the files were usable in IES-VE.

### 5.2 Feedback process

Please provide feedback on the usability and functionality of this weather data to the CSIRO via the contact details on the Data Shop website. If you are happy to be approached for your advice on how the weather files could be improved, please provide your contact details.

The predictive weather files have undergone checking and testing and were found to be generally suitable for use on EnergyPlus and IES-VE for modelling commercial buildings in Australia.

However the CSIRO and the Department of Industry, Science, Energy and Resources (the department) welcome feedback on the usability and functionality of this weather data for the purposes of testing commercial building performance for resilience against potential future climate conditions when conducting:

- HVAC sizing
- Building fabric design
- Thermal comfort assessment



In 2022 the department will set up a technical working group to review the success of this project. The group will be asked to provide feedback on the ease of access to the weather data, its suitability for use by commercial building modellers and the level of awareness of how to access and use the weather data. The group will also be asked to provide suggestions for improvement. The department will collate the feedback and liaise with the CSIRO to implement improvements which are agreed by the department.

## 6 Data version control

The datasets are likely to be updated from time to time. This could be due to fixing errors discovered in the data, incorporating new weather data, or other reasons. Older versions of the datasets will still be available if required. The superseded versions will be available in the Data Shop on the same page as the current version, but clearly marked as archived versions.

Table 5 lists all versions of the dataset 'Predictive weather files in .epw format' that have been available in the Data Shop, the date they were added, and the changes made.

Table 6 lists all versions of the dataset 'Predictive weather files in NatHERS format' that have been available in the Data Shop, the date they were added, and the changes made.

**Table 5 Data version control - Predictive weather files in .epw format**

DATASET ZIP FILE NAME	DATE ADDED TO DATA SHOP	CHANGES
<b>PredictiveWeatherFilesEpw_20210712.zip</b>	2021-08-13	First version of dataset publicly available

**Table 6 Data version control - Predictive weather files in NatHERS format**

DATASET ZIP FILE NAME	DATE ADDED TO DATA SHOP	CHANGES
<b>PredictiveWeatherFilesNatHERS_20210628.zip</b>	2021-08-13	First version of dataset publicly available

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