ASIA-PACIFIC SOLAR RESEARCH CONFERENCE

30 November – 2 December 2020
Melbourne, Australia

Verification of ClimateCypher Climate Data Outputs with System Advisor Model (SAM)

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The P10, P50 and P90 data in statistics refer to a value that is expected to be exceeded in 10%, 50% and 90% of the cases in a given temporal sample and may be done through the process of Monte Carlo simulation (Dobos, Kasberg and Gilman, 2012)). The data samples used in this analysis are of two kinds: the weather data of a particular location recorded for generally 28 years (and at least 15 years) and the energy output obtained from a simulated solar PV generator during these specific years. ClimateCypher is an in-house software package of Exemplary Energy capable of reading files containing satellite-derived solar data and surface-measured weather data including any ground measured solar data. Currently it has the capability of producing the weather data for the user required period of years and also processes the Reference Meteorological Years (RMYs). Both these outputs are provided in the TMY (Typical Meteorological Year) and ACDB (Australian Climate Data Bank) formats. RMYs (A, B or C according to the weighting given to the weather elements, with A having the greatest weighting given to solar irradiation) represent the entire time duration of the weather data in a single synthetized year and provides a convenient way to model building and energy systems (Lee, 2011).

This work focused on enhancing the ClimateCypher software by making it capable of accurately processing the P10 and P90 years. In another words, ClimateCypher should select the months that will comprise the atypical years which will be the 10^{th} and 90^{th} percentile from each of the months during the decades in the analysis. As the actual weather data is highly unpredictable, analysing the P10 and P90 years will help in calculating the uncertainty involved in the weather data and various associated calculations. For instance, the P90 data is used by financers and lenders to access the risks they are involved with by committing to a renewable energy project.

This analysis used a residential solar electricity generation system which consists of 3kW solar photovoltaic panels connected to an inverter with a DC to AC conversion ratio of 1.2. Hence the inverter size of the simulation was 2.5 kW_{ac}. The System Advisor Model (SAM) was developed by the US National Renewable Energy Laboratory (NREL) and was used to simulate the energy output from the weather data input into the software. The P50/P90 simulate feature of SAM performed the P10, P50 and P90 analysis and gave the 10^{th}, 50^{th} and 90^{th} percentiles of the energy output from the PV system for a minimum of 10 years of single year weather data (National Renewable Energy Laboratory, 2020).

Methodology:

The ClimateCypher was developed to generate the P10 and P90 weather files by the most appropriate 12 calendar months and concatenating them such that the resultant synthesised year closely matches the 10 percentile and 90 percentile criteria. The data was analysed based on the National Construction Code (NCC) climate zone of the location and the parameter used for splitting was empirically determined after several iterations in ClimateCypher and comparing output of each iteration with that of the 10^{th} and 90^{th} percentile of energy output obtained from the decades-long full weather files input into SAM.

The Australian Building Codes Board (ABCB) has segmented Australia into eight climate zones as shown in Figure 1 (Australian Building Codes Board, 2019). This analysis was performed for all eight Australian capital cities and two other locations to take into consideration all the climate zones defined by the ABCB. The locations are listed in Table I.

Table I. List of locations for which analysis is performed and their details

Location	State	Climate Zone	Climate Zone Description	Longitude (°E)	Latitude (°N)	Elevation (m)
Darwin	NT	1	High humidity summer and warm winter	130.9	-12.4	30.4
Brisbane	QLD	2	Warm humid summer and mild winter	153.1	-27.4	4
Tennant Creek	NT	3	Hot dry summer and warm winter	134.1	-19.6	376
Alice Springs	NT	3 and 4	Hot dry summer and warm / cool winter	133.9	-23.8	546
Oodnadatta	SA	4	Hot dry summer and cool winter	135.5	-27.6	117
Sydney	NSW	5	Warm temperate	151.2	-33.9	6
Adelaide	SA	5	Warm temperate	138.6	-34.9	48
Perth	WA	5	Warm temperate	116.0	-31.9	15.4
Melbourne	VIC	6	Mild temperate	145.0	-37.8	31.2
Canberra	ACT	7	Cool Temperate	149.2	-35.3	578.4
Hobart	TAS	7	Cool Temperate	147.3	-42.9	4
Cabramurra	NSW	8	Alpine	148.4	-35.9	1482.4

For each of the NCC climate zones, after iterative analysis, the empirically determined month selection parameter that was used in ClimateCypher was established as shown in Table II:

Table II. List of Climate Zones, locations and their month selection parameters

Climate Zone	P10	P90	Analysis Location
1	0.35	0.75	Darwin
2	0.35	0.80	Brisbane
3	0.35	0.80	Tennant Creek, Alice Springs
4	0.35	0.80	Oodnadatta, Alice Springs
5	0.35	0.75	Adelaide, Perth, Sydney
6	0.20	0.80	Melbourne
7	0.30	0.75	Canberra, Hobart
8	0.35	0.75	Cabramurra

Result:
Based on the empirically determined parameters shown in the Table II, ClimateCypher produced the P90 and P10 months for the period from 1990 to 2017. These ClimateCypher produced P10 and P90 data was then input into SAM and the yearly energy output corresponding to the ClimateCypher determined P10 and P90 data was obtained.

SAM also processed the yearly energy outputs for this period by taking the actual yearly weather data and also determined the P10 and P90 energy which will be known as SAM P10 and P90 in this analysis.

These results were plotted using a bar graph and are represented below (Figures 2-9) for each climate zone. Note that each has its vertical scale truncated to emphasise differences. The year-to-year variation is actually much less than it appears.

Conclusion
From the bar graphs (Figures 2-9) showing the yearly energy outputs in ascending order, the SAM calculated P10 and P90 energy outputs and the energy outputs obtained using the ClimateCypher, it can be observed that the ClimateCypher outputs are in close match with the SAM obtained P10 and P90 values. Hence it is confirmed that the ClimateCypher produced reliable P10 and P90 data for the 28 year period from 1990 to 2017.

Scope of Future Work
Further work on ClimateCypher will include refinement of the month selection parameters and enhancing the software to produce eXtreme Meteorological Year (XMY) data which will be the data corresponding to hypothetical years with extreme weather conditions. This will be achieved in ClimateCypher by producing P00 and P99 data for weather data for a particular period. This will be helpful in predicting the worst case scenarios in case of building simulation or PV power plant design where the design should be conservative enough to handle extreme weather conditions like high temperatures and sustained extremely high or low solar irradiation (occasionally greater than the nominal 1 kW/m^2 value) (Crawley & Lawrie, 2015). However, the selection technique we propose will not target extreme hourly values but rather unusually long durations of cloudiness or of clear skies.

Acknowledgements
The authors acknowledge the Australian Bureau of Meteorology as the source of all the raw data and the other members of the Exemplary team: Yoke Yeong Fung, Naman Jain and Chun Yin Wu.

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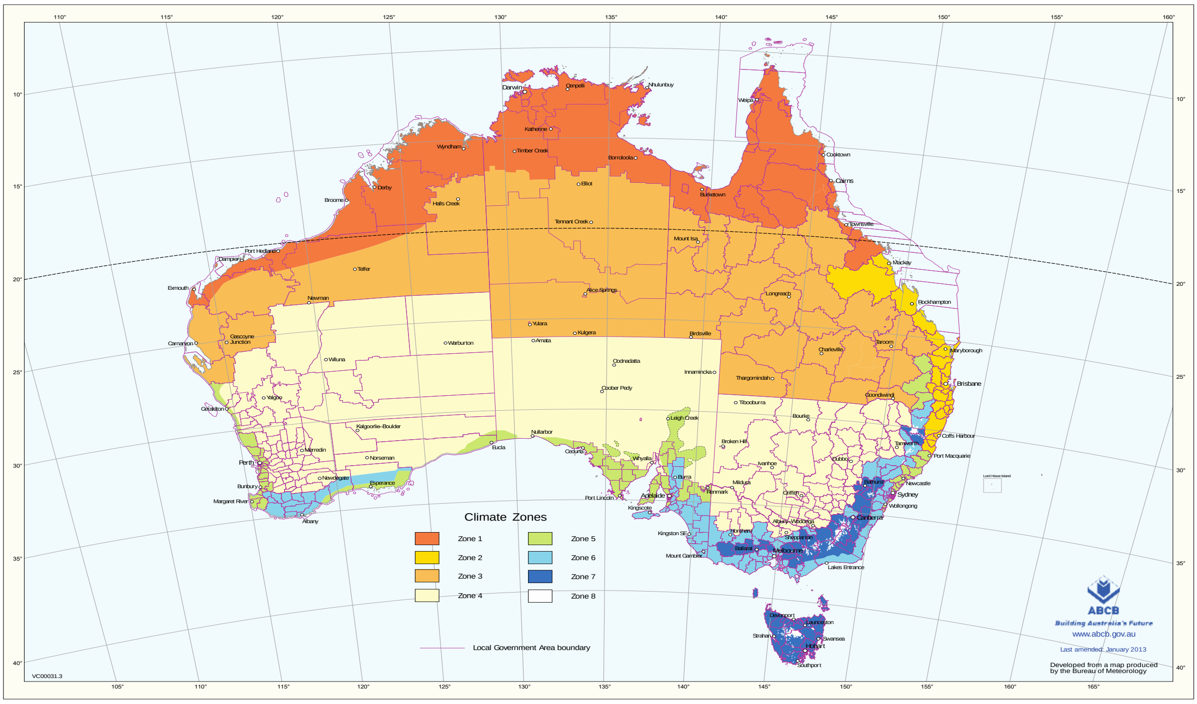

Figure 1. Climate zone map of Australia

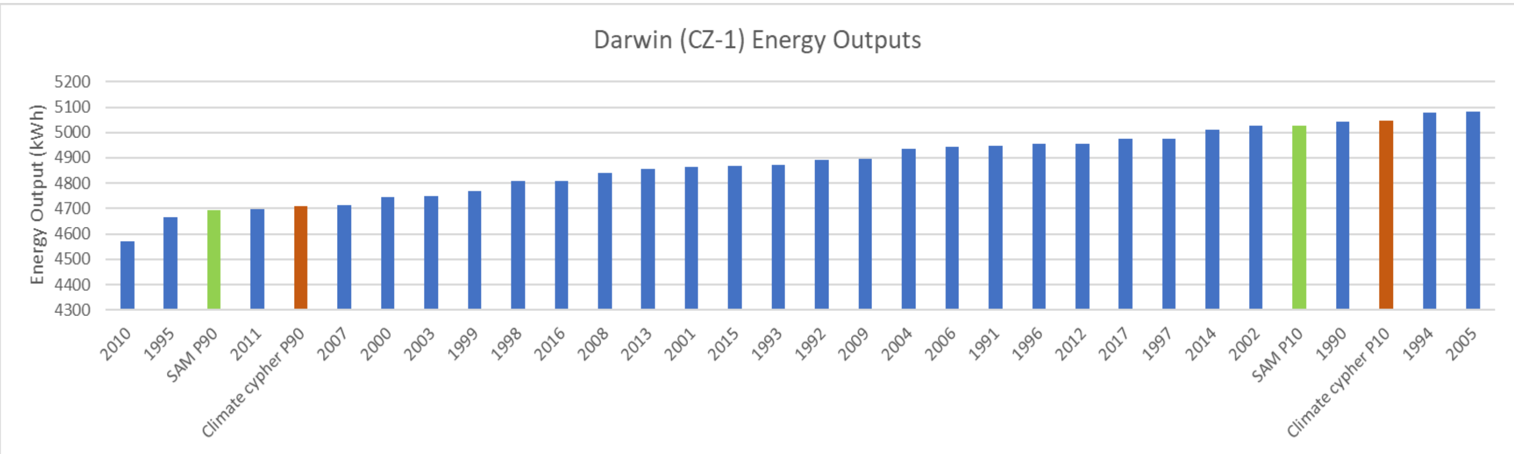

Figure 3: Energy outputs for Climate Zone 1 (Darwin)

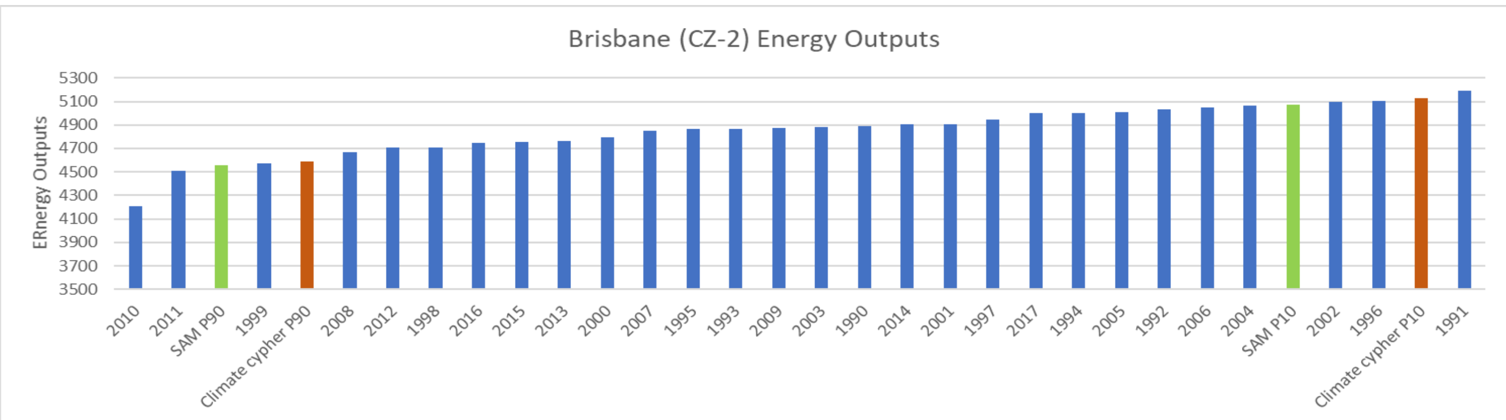

Figure 2: Energy outputs for Climate Zone 2 (Brisbane)

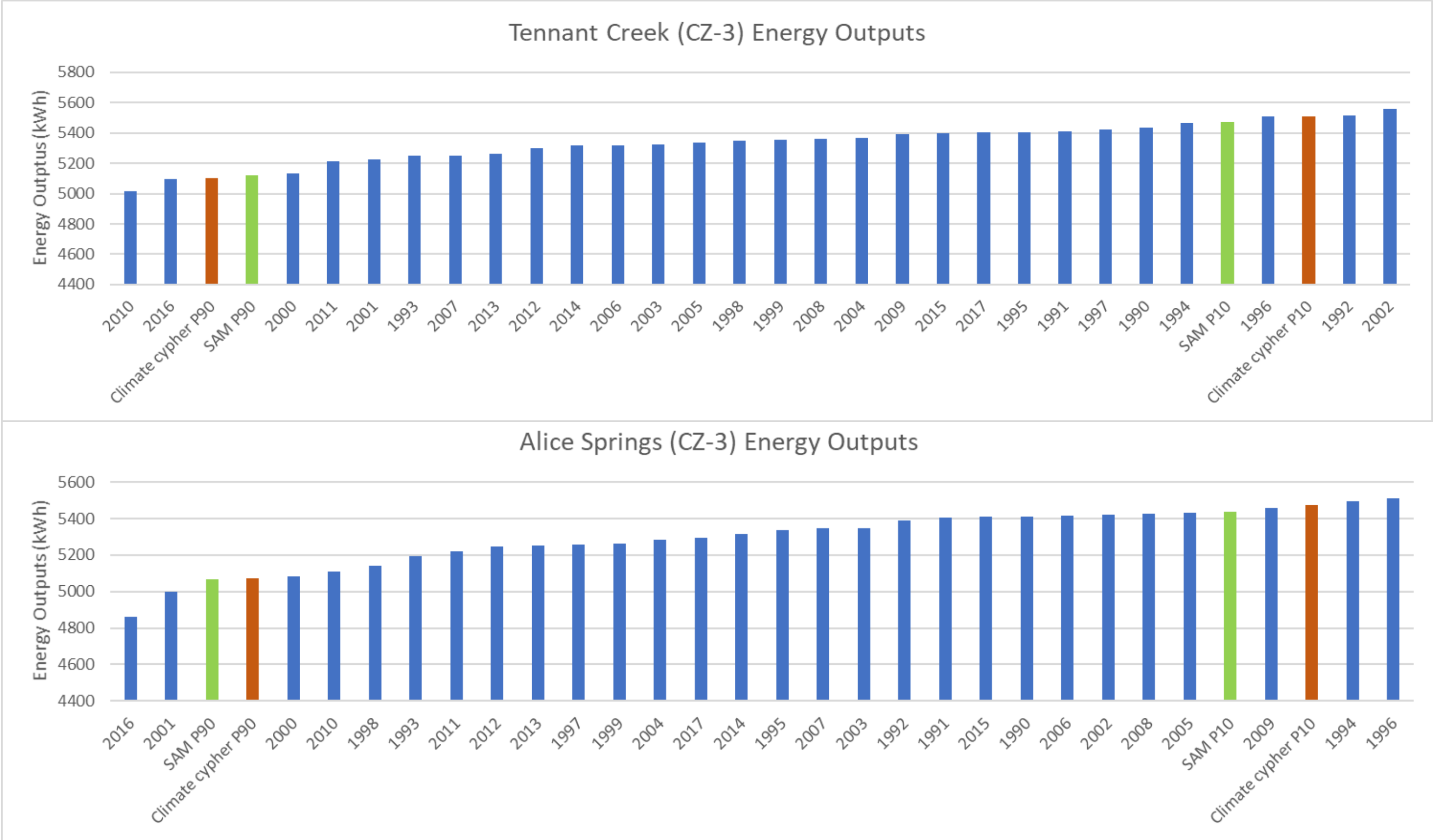

Figure 4: Energy outputs for Climate Zone 3 (Top: Tennant Creek, Bottom: Alice Springs)

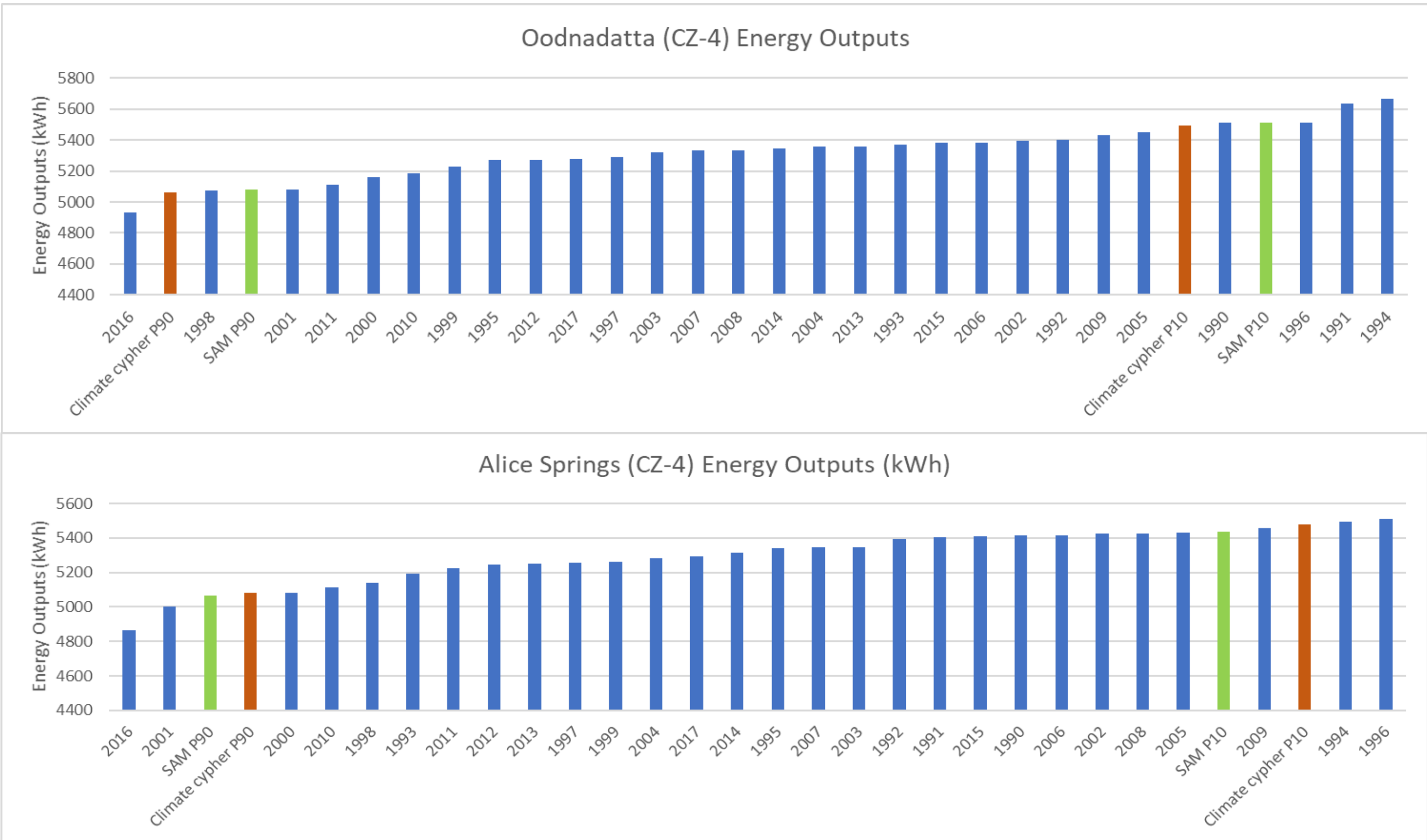

Figure 5: Energy outputs for Climate Zone 4 (Top: Oodnadatta, Bottom: Alice Springs)

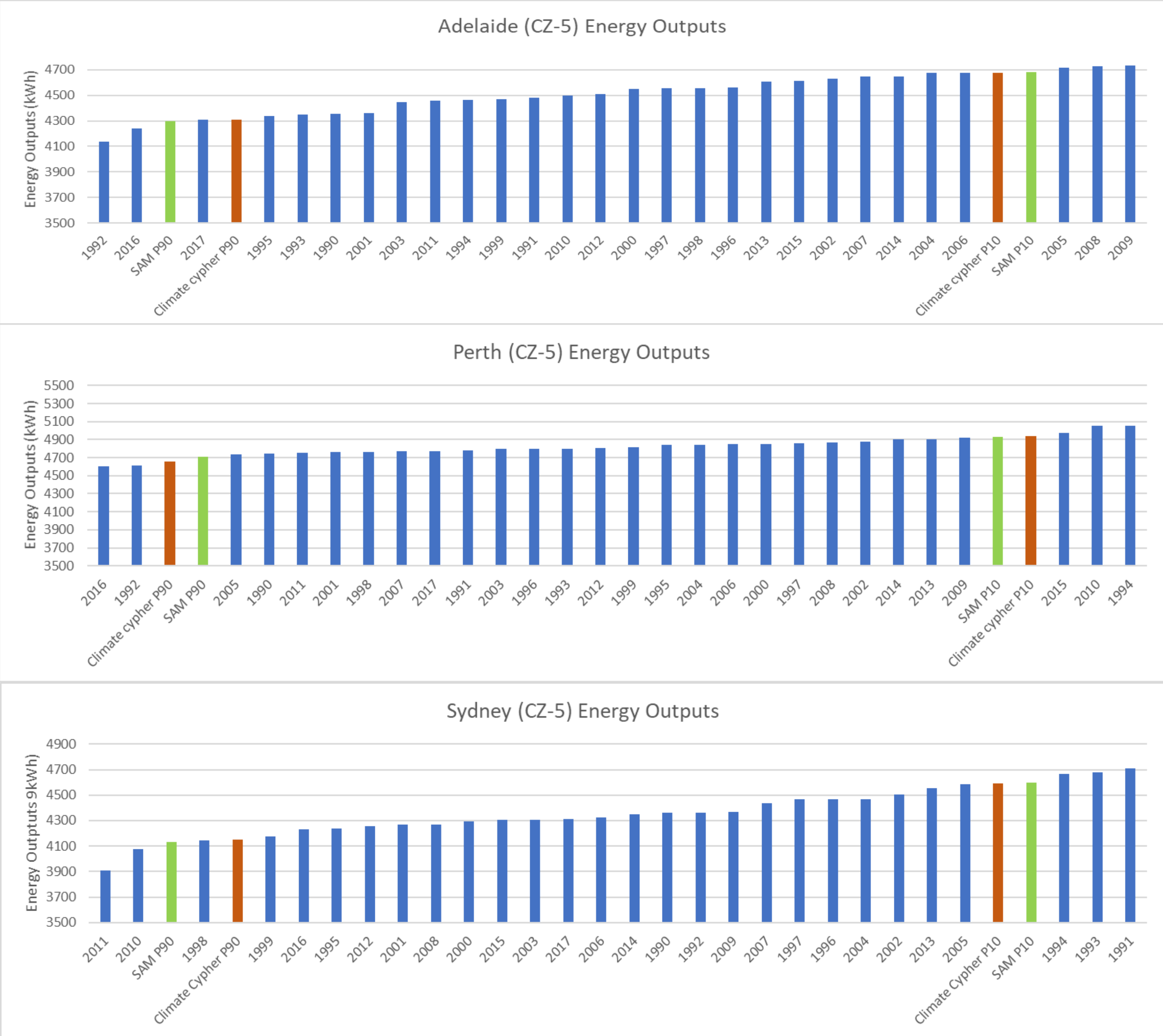

Figure 6: Energy outputs for Climate Zone 5 (Top: Adelaide, Middle: Perth, Bottom: Sydney)

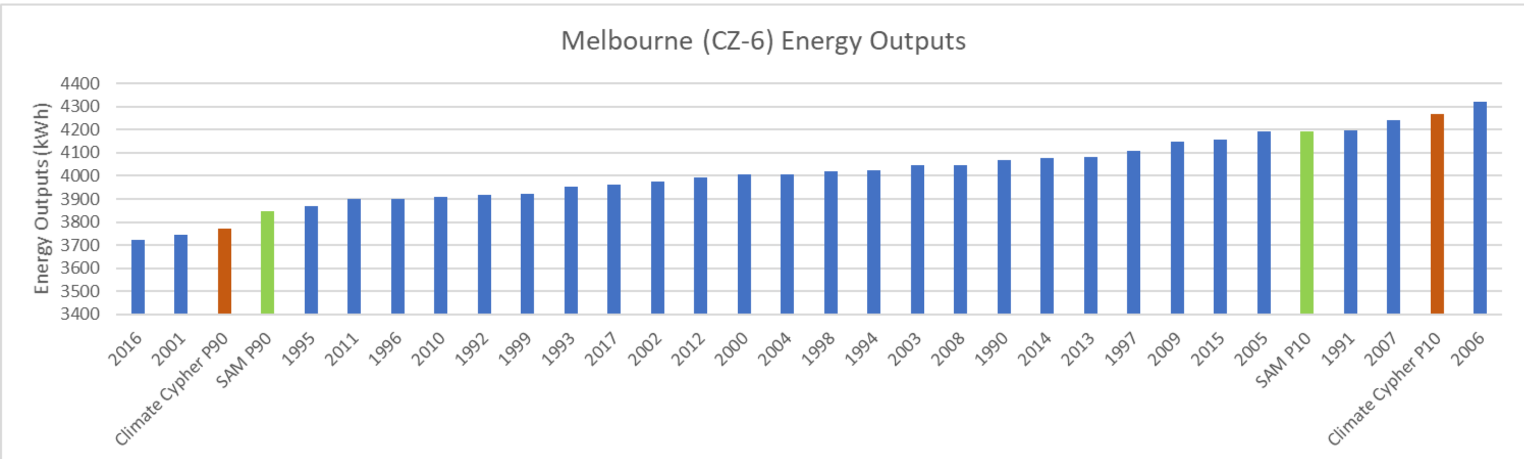

Figure 7: Energy outputs for Climate Zone 6 (Melbourne)

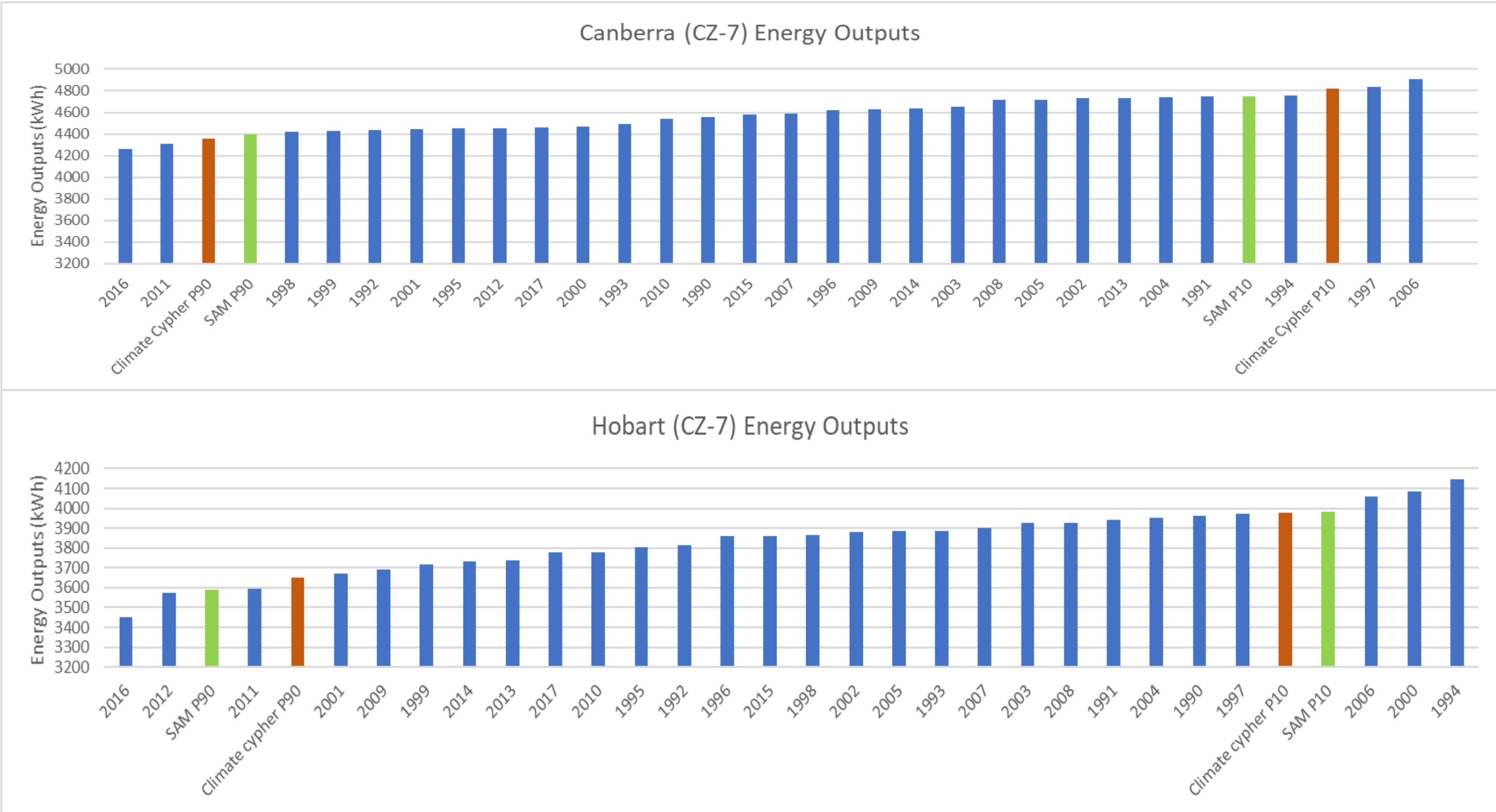

Figure 8: Energy outputs for Climate Zone 7 (Top: Canberra, Bottom: Hobart)

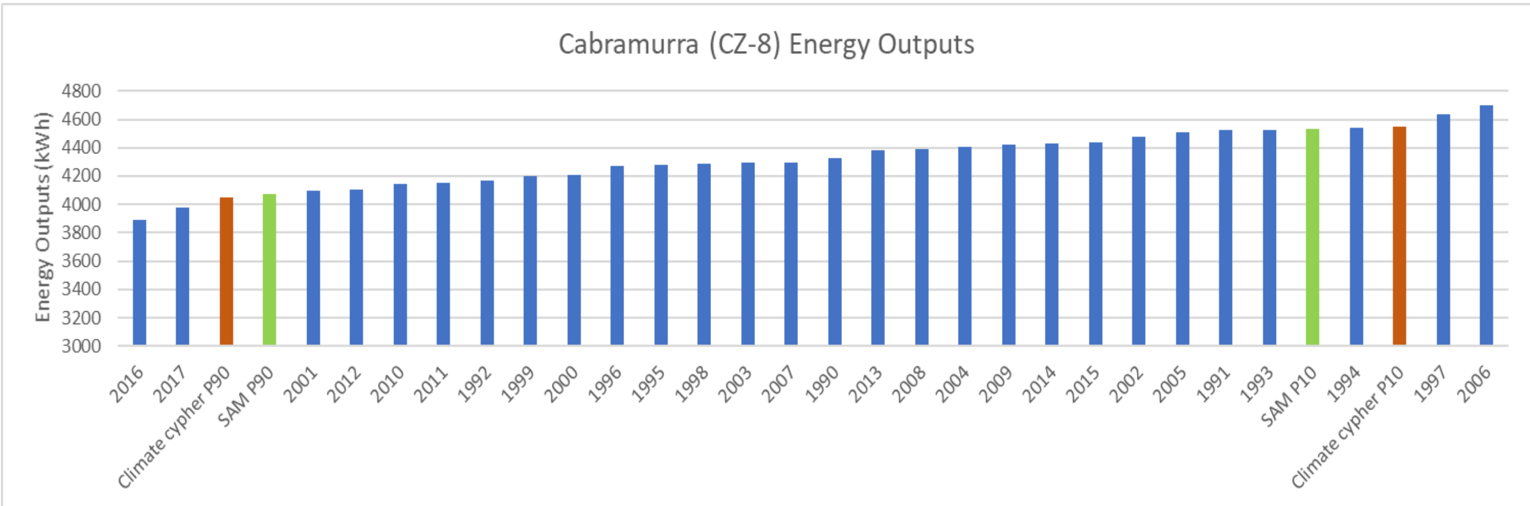

Figure 9: Energy outputs for Climate Zone 8 (Cabramurra)