BEYOND TMY: CLIMATE DATA FOR SPECIFIC APPLICATIONS

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ABSTRACT

In many simulations of energy systems, climate is represented as Typical Meteorological Year (TMY) data. Because of the format implications of the acronym TMY when used outside Australia, these are locally called a Reference Meteorological Year (RMY). The approach derives hourly meteorological variables from historic records to represent typical annual climate for a given location. While meeting the need for comparability and indicativeness, the technique suffers from an incapacity to provide information on extreme weather events, like heat waves or passing tropical cyclones, or for specific actual periods of concern.

This paper describes a modified approach whereby representative data may be selected for a targeted purpose. The data is converted to a format appropriate to the simulation under consideration, checked for errors, data omissions "filled" and applied to the model.

Applications may include:

- Model validation and calibration using real time weather data coincident with other empirical measures like solar system output or building energy consumption or temperature (especially if unconditioned).
- Building or system monitoring for underperformance to indicate early restorative action.
- Adjustment of actual output or consumption in a real year to reflect reasonably anticipated outcomes in the actual year relative to those in the RMY.
- Design assessment against challenging weather conditions like a hot dry (El Nino) year or a windy wet (La Nina) year or some shorter duration subset of such periods for plant sizing and/or temperature excursion prediction.
- Forecast future weather in anticipation of climate change (global warming).

BACKGROUND

An updated version of the Australian Climate Data Bank software (MakeACDB v9) and Reference Meteorological Year (RMY) climate files have been announced.

The updated MakeACDB software includes various enhancements over the previous version, including:

- Use of hourly historic data where available.
- Various internal validity checks for humidity calculations.
- Enhanced hourly estimation of direct and diffuse irradiance from daily global extraterrestrial measurements.
- Representation of 11 new climate locations.
- Ability to select more options for weather element weightings in selecting the 12 individual months to comprise the RMY.

In the RMY datasets, “representative” months were selected from the historic record according to their similarity to the long-term average. For example, the “February” data in the RMY for a location with a 40-year record will be the *most average* of the 40 historic Februarys. The average was defined as the weighted multivariate mean of weather elements (maximum, minimum and mean dry-bulb temperature; max, min and mean wet-bulb temperature; max and mean wind speed; total global irradiance; and total diffuse irradiance), with weights as described below.

Originally, the primary application of ACDB RMYs was in simulating the thermal performance of houses. Weights were decided accordingly: solar radiation was awarded the highest weight, followed by mean dry- and wet-bulb temperatures. Details are presented in Tab. 1. The weights in Tab. 2 were used for sites where diffuse irradiance was not measured terrestrially.

Tab. 1: Weights for RMY with Diffuse

Weather Element	**Weighting**
Max Temp	1/20
Min Temp	1/20
Mean Temp	2/20
Max Wet Bulb Temp	1/20
Min Wet Bulb Temp	1/20
Mean Wet Bulb Temp	2/20
Max Wind Velocity	1/20
Mean Wind Velocity	1/20
Global Radiation	5/20
Diffuse Radiation	5/20

Tab. 2: Weights for RMY without Diffuse

Index	**Weighting**
Max Temp	1/15
Min Temp	1/15
Mean Temp	2/15
Max Wet Bulb Temp	1/15
Min Wet Bulb Temp	1/15
Mean Wet Bulb Temp	2/15
Max Wind Velocity	1/15
Mean Wind Velocity	1/15
Global Radiation	5/15
Diffuse Radiation	0/15

FURTHER ENHANCEMENTS

Along with the improvements over previous versions of the ACDB software and data described above, a number of further enhancements to the data sets may be made. In general, these enhancements involve using various alternatives to the RMY-month selection procedure. Weights applied in the calculation of the weighted mean may be modified; more recent years may be weighted more heavily to produce a bias towards more recent years' data being representative of future climate expectations; or the data may be selected on the basis of being representative of extremes as opposed to averages (the eXtreme Meteorological Year, or XMY).

Modifications to Weather Element Weights

For larger buildings where the centre zone dominates the performance, sometimes called "Load Dominated" buildings, temperature and humidity are more important than solar radiation, and wind is only of minor interest. However, for an RMY for a wind farm proponent, the highest weight should be given to wind speed, and then probably temperature, given that electricity demand depends in part on temperature. Various possibilities are presented below (Tab. 3 to Tab. 5):

Tab. 3: Example – potential weights for large office buildings

Weather Element	**Weighting**
Max Temp	1/12
Min Temp	1/12
Mean Temp	2/12
Max Wet Bulb Temp	1/12
Min Wet Bulb Temp	1/12
Mean Wet Bulb Temp	2/12
Max Wind Velocity	1/12
Mean Wind Velocity	1/12
Global Radiation	2/12
Diffuse Radiation	0/12

Tab. 4: Example – potential weights for wind farms

Weather Element	Weighting
Max Temp	1/15
Min Temp	1/15
Mean Temp	1/15
Max Wet Bulb Temp	0/15
Min Wet Bulb Temp	0/15
Mean Wet Bulb Temp	0/15
Max Wind Velocity	5/15
Mean Wind Velocity	5/15
Global Radiation	1/15
Diffuse Radiation	1/15

Tab. 5: Example – potential weights solar-sensitive infrastructure (e.g. PV or solar thermal generators)

Weather Element	Weighting
Max Temp	1/20
Min Temp	0/20
Mean Temp	1/20
Max Wet Bulb Temp	0/20
Min Wet Bulb Temp	0/20
Mean Wet Bulb Temp	0/20
Max Wind Velocity	2/20
Mean Wind Velocity	1/20
Global Radiation	10/20
Diffuse Radiation	5/20

These examples represent just three possibilities. ANZSES is now able to provide representative meteorological data to any specification of weather element weights.

Ersatz Future Climates

Lee and Ferrari (2006) described a method for producing RMY data sets for future climate scenarios by combining CSIRO climate projections with *baseline* data representative of current climate.

Since the completion of that work, the CSIRO (2007) has undertaken more accurate modelling and has updated those projections. The authors are presently negotiating to obtain those projections in a format which eliminates some of the shortfalls of the forecasts used in their previous work. RMY data sets will be created for the CSIRO baseline period (centred at 1990), and combined with CSIRO's improved climate projections to produce representative future meteorological data sets (FMYs).

Representative Extremes

The assessment of designs against challenging weather conditions first requires definition of those extreme climate scenarios for any given location. While representative eXtreme Meteorological Year (XMY) data sets still require full definition, examples include determining performance during a hot dry (El Nino) year, a windy wet (La Nina) year, or some shorter duration subset of such periods. An alternative is the amalgamation of "hottest summer" with "coldest winter" months:

- For "cooling" months (November to March in the temperate zone), high temperatures (minimum, maximum, mean temperature) score well, low temperatures score badly.
- For "heating" months (May to September in the temperate zone), low temperatures score well, high temperatures score badly.
- For "other" months, (April, October) extreme (high or low) temperatures score well, average scores badly.

Selection According to Simulation Results

Morrison and Litvak (1999) described a procedure for selecting representative months on the basis of simulation results. A large number of models are simulated using data for the entire recorded weather history. The most typical month is that which produces a simulated energy result closest to the average of results for all equivalent months in the decades studied. The set of models is selected to represent the data's intended application - the Morrison and Litvak work was interested in solar water heater simulation, and the models used were of solar water heaters including unglazed pool heaters. Alternatives include buildings, PV systems, high temperature solar thermal systems, and others.

This method has the advantage that the relative importance of each weather element need not be defined by abstract judgement of the element weightings pertinent to the application. The approach suffers from the relative importance of parameters varying depending on the specification of the models used. This is offset by selecting a large set of models, although the large number of simulations combined with the long-term climate data sets can become prohibitively computationally expensive.

New Sites

The 2008 update to the ACDB included 11 additional climate zones as described in Tab. 6.

The extents of these and existing NatHERS climate zones are described in the ACDB map and associated documentation which is available online (DEWHA 2008).

Where demand arises, new climate data sets may be produced for any site within reasonable proximity to a meteorological station with a long-term record (generally 14 years is a minimum for reliable inference of the long term means).

Tab. 6: New ACDB climate zones

ACDB CZ	ACDB name	State	Alt. (m)	Long.	Lat.	2LA	BCA CZ	BOM Site	WMO
CZ0502	Toowoomba	QLD	691	151.93	-27.58	TW	5	41529	95551
CZ0107	Atherton	QLD	752	145.48	-17.26	AT	1	31210	94288
CZ0204	Maleny	QLD	425	152.85	-26.77	MN	2	40284	95566
CZ0704	Sub-Alpine (Cooma Airport)	NSW	930	148.97	-36.29	SU	7	70217	94921
CZ0601	Blue Mountains	NSW	1080	149.00	-21.50	BL	6	63292	94743
CZ0511	Parramatta	NSW	55	151.00	-33.81	PA	5	66137	94765
CZ0407	Tamworth	NSW	404	150.84	-31.08	TA	4	55325	95762
CZ0608	Coldstream	VIC	83	145.41	-37.73	CS	6	86383	94864
CZ0405	Roxby Downs	SA	98.5	136.87	-30.45	RX	4	16096	95658
CZ0515	Adelaide Coastal (AMO)	SA	48	138.53	-34.96	AC	5	23034	94672
CZ0103	Katherine	NT	106.9	132.27	-14.44	KN	1	14932	94131

ACDB CZ	Australian Climate Data Bank Climate Zone
2LA	Two Letter Acronym
BCA CZ	Building Code of Australia Climate Zone
BOM Site	Bureau of Meteorology Site
WMO	World Meteorological Organisation

Real-time Data

Real-time data, provided by BOM, can be applied to simulations for various purposes, including:

- Model calibration using real time weather data coincident with other empirical measures like solar system output or building energy consumption or temperature (especially if unconditioned);
- Building or system monitoring for underperformance to indicate early restorative action; or
- Adjustment of actual output or consumption in a real year to reflect reasonably anticipated outcomes in the actual year relative to the RMY.

An application of real-time year-to-date data (RTY) is presented below.

Provision in Various Formats

While the ACDB is produced and sold to a specific format required for house energy rating software (HERS), any of the datasets described above can be provided in any format to the user's requirements.

APPLICATION AND RESULTS

A small study compared results of simulations using RMY data for Canberra from the 2008 and 2005 ACDB sets against the real-time year-to-date and 40-year historical averages.

The data was applied to eleven house models in the CSIRO thermal simulation software AccuRate. Three of the houses were selected from a large collection of results from prior simulation studies and consisted of the least, median and most energy intensive in the set. The remaining eight models were created from “NatHERS Example House 1”, a dwelling design used in many prior energy efficiency studies. Heavyweight and lightweight versions of the model employed concrete slab and timber floors, respectively. These were rotated to the four cardinal orientations, providing eight models from that one design. Each orientation had its fenestration widths adjusted to just meet the BCA DTS[1] standards for Canberra Dwellings (BCA CZ 7) which theoretically makes them just barely 5-star in energy efficiency rating (EER) terms.

All eleven models were simulated in the Canberra climate, using the 2005 RMY-A, 2008 RMY-A,-B and -C, real-time year-to-date (RTY) up to 28 August 2008, an RMY-A computed from the decade of historical data (decade-to-date, DTD) to end 2007, and four-decade historical data (1967-2007).

An RMY-A is one selected using the weightings of Tab. 1, RMY-B is from Tab. 2 and RMY-C is from Tab. 3.

A sample of simulation results are presented in Fig. 1 to Fig. 5. The bar plots indicate the simulated energy consumption using each climate data set as compared to the average simulated energy consumption using the full four decades of data, which is plotted as a horizontal line.

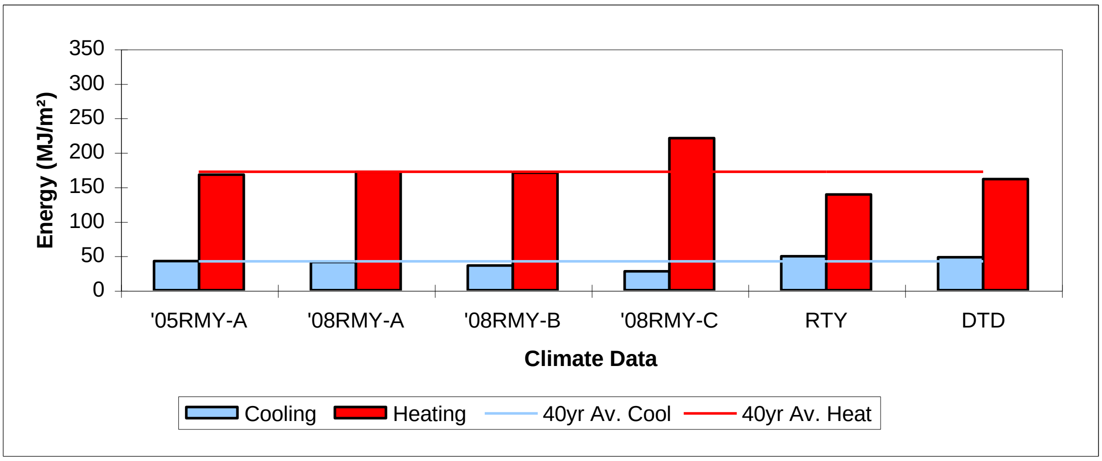

Fig. 1: Simulated consumption of the “heavyweight” dwelling at 90° orientation

[1] Building Code of Australia Deemed to Satisfy

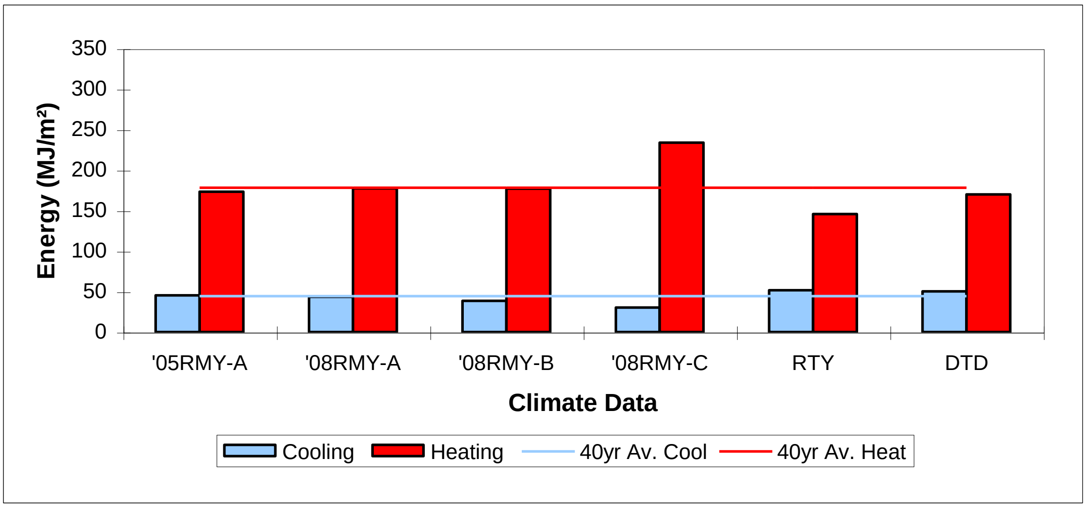

Fig. 2: Simulated consumption of the "lightweight" dwelling at 0° orientation

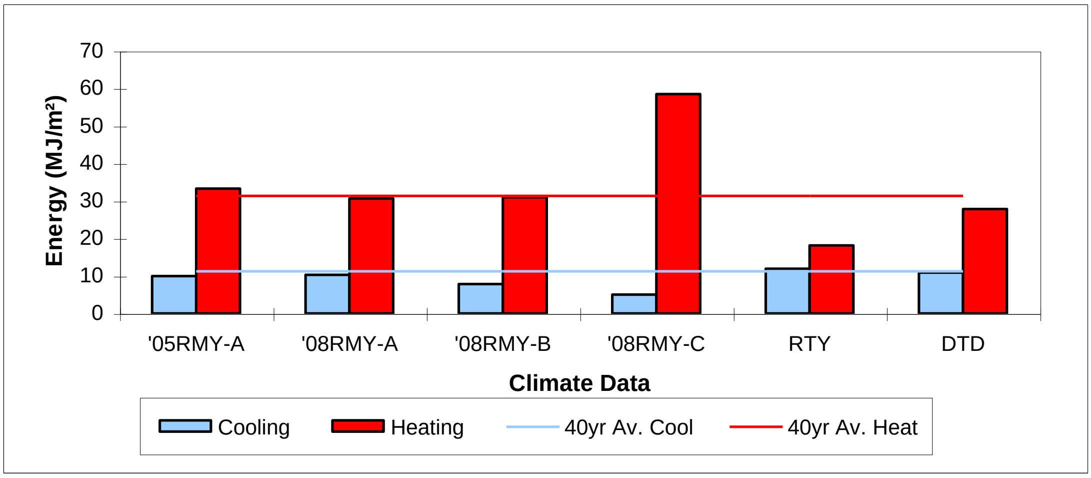

Fig. 3: Simulated consumption of the "best" dwelling (note change to vertical scale)

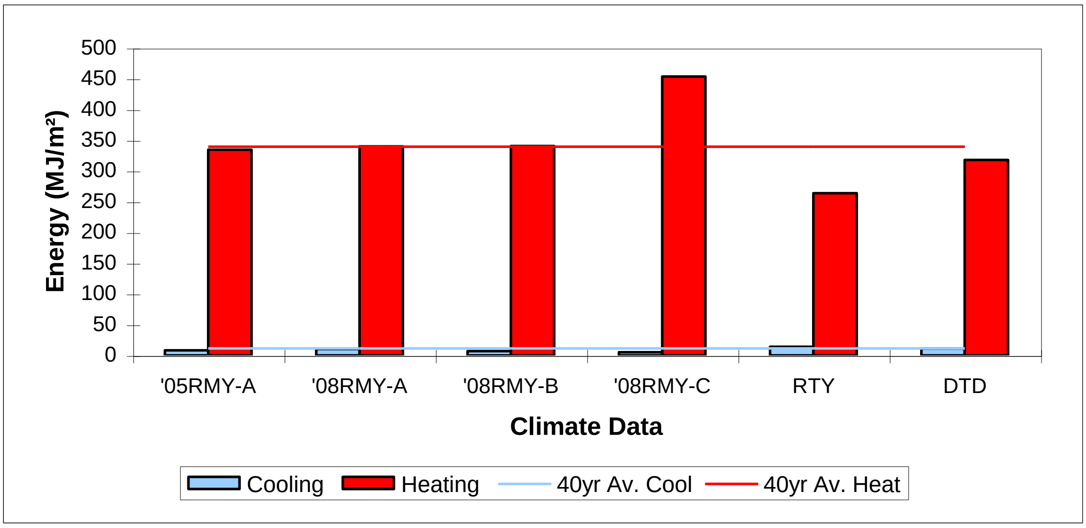

Fig. 4: Simulated consumption of the "median" dwelling (note change in vertical scale)

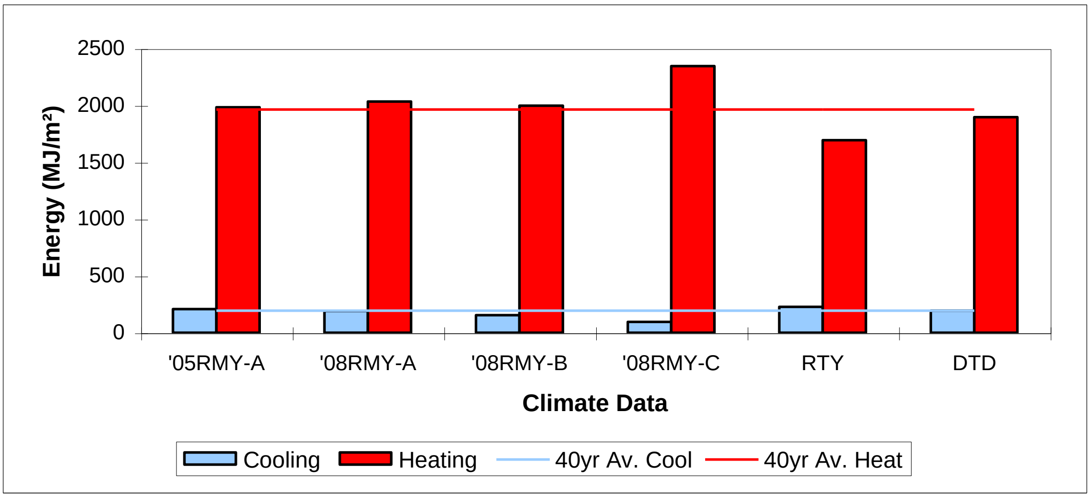

Fig. 5: Simulated consumption of the "worst" dwelling (note change in vertical scale)

Clearly, results of simulations using RMY-A and RMY-B correlate quite closely to the historical average. The deviation of results using RMY-C from the historical average demonstrates the importance of weighting weather elements in accordance with the data's application.

The results of simulations under RTY conditions reflect the reduced demand for heating (and increased demand for cooling) in Canberra over the previous twelve months, due to slightly warmer than average climatic conditions. The results using DTD data echo this, revealing the effect of temperature increase due to climate change (CSIRO 2007, Ch.2). Both RTY and DTD years were compiled using the "A" weighting of the weather elements (Tab. 1).

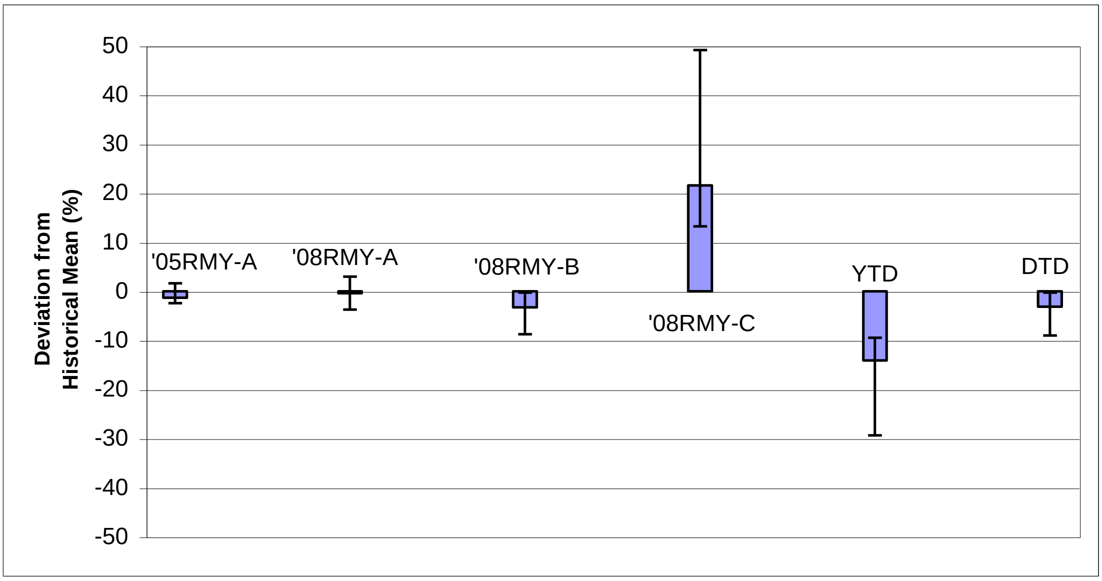

Fig. 6: Average difference between simulation results using representative data and historical mean

Fig. 6 presents the difference between simulation results using the historical average and the representative data sets. For the most part, close agreement was found between the average and RMY results. The results using the 2008 RMY-C dataset stand in contrast to this, indicating the potential effect of inappropriate weather element weights in RMY-month selection.

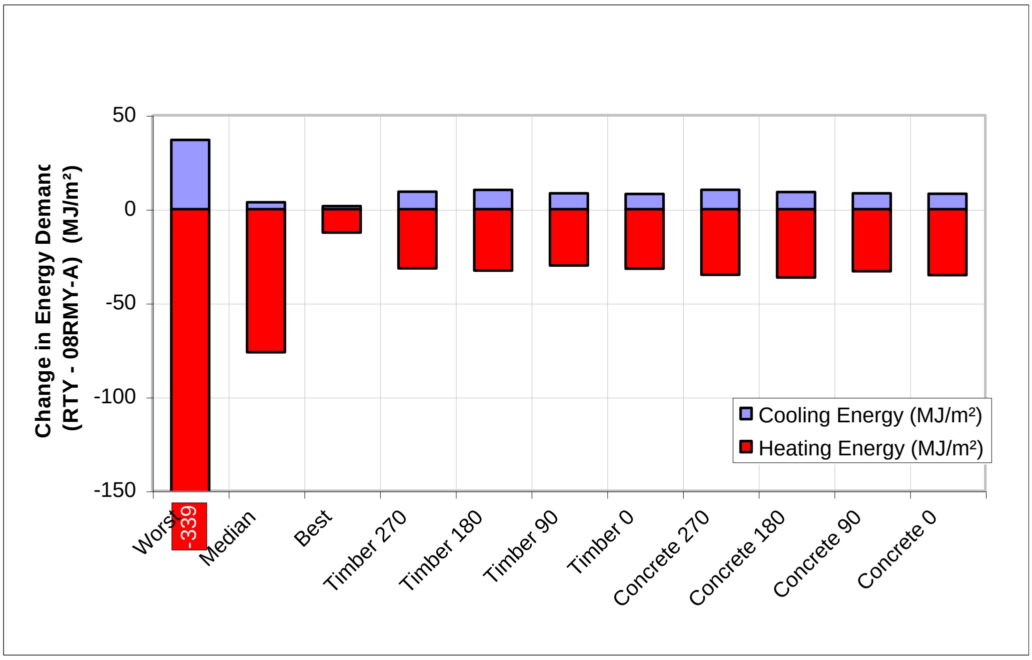

Fig. 7: Total Heating and Cooling Energy differences RTY versus 2008 RMY-A

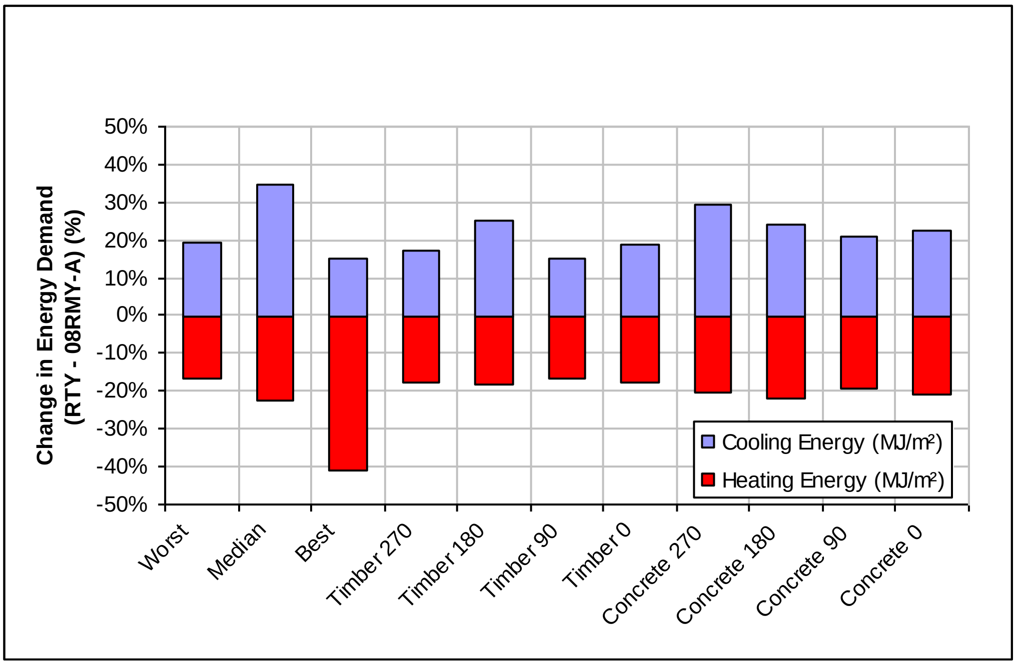

Fig. 8: Total Heating and Cooling Energy between RTY and 2008 RMY-A as a percentage of 2008 RMY-A

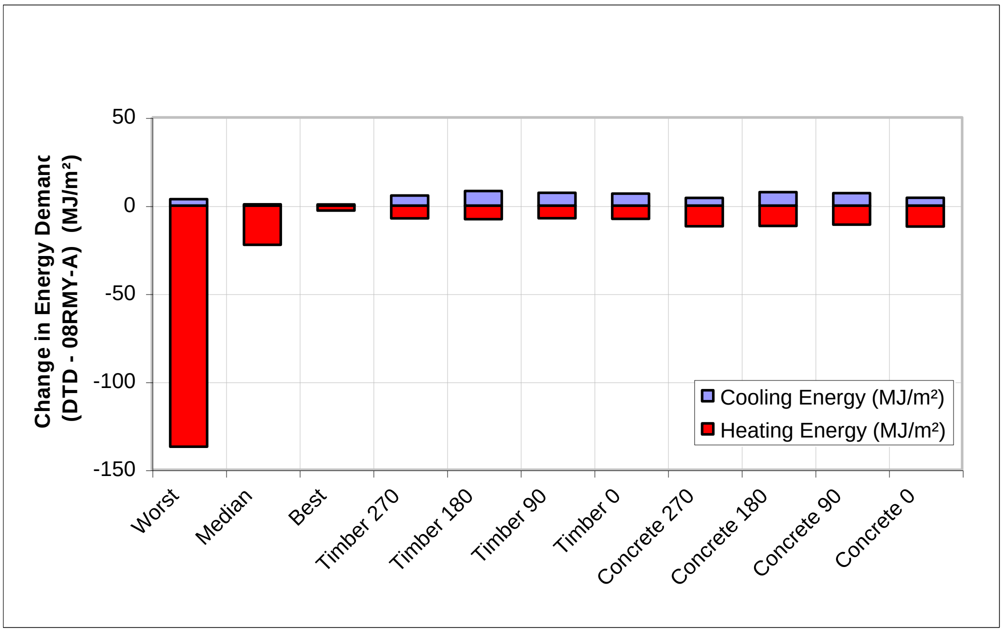

Fig. 9: Total Heating and Cooling energy differences between DTD and 2008 RMY-A

The heating energy demand of both the RTY and DTD meteorological years relative to the four-decade representative year (2008 RMY-A) is significantly smaller: by ~21% and ~6% respectively. Cooling demand is increased by ~22% in the RTY and ~12% in the DTD relative to the 2008 RMY-A. While nothing can be reliably concluded from the single year sample (RTY), in the case of the DTD year, this probably reflects the effect of past climate change and provides some indication of the potential effect of future warming.

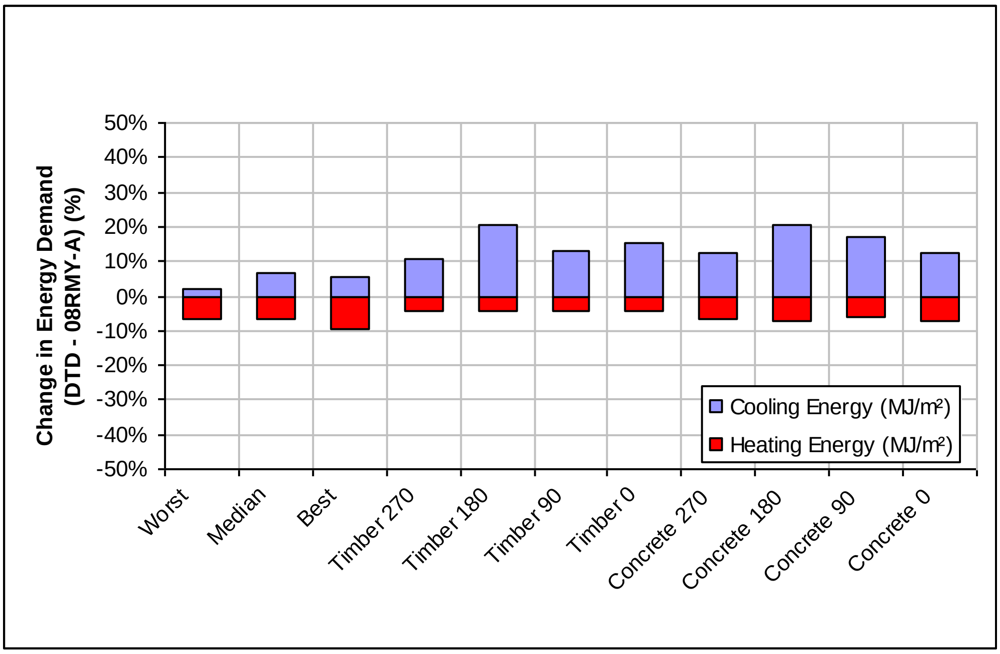

Fig. 10: Total Heating and Cooling Energy between DTD and 2008 RMY-A as a percentage of the 2008 RMY-A

CONCLUSIONS

The 2008 update to the Australian Climate Data Bank (ACDB) and its software MakeACDB included various enhancements over previous versions. These enhancements produce high quality representative meteorological data sets suited to application in building thermal simulation.

Representative meteorological data sets were applied to the simulation of a number of dwellings using the CSIRO software AccuRate. Results indicate the importance of selecting suitable representative data for each application.

Further work may produce better data for other applications. This paper describes several variations on the RMY methodology to produce data sets for application to other types of weather-affected systems.

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BRIEF BIOGRAPHY OF PRESENTER

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An architect by initial training, Trevor is a consultant on energy conservation in the built environment through his multi-disciplinary firm Energy Partners. He is the lead author of the Australian Solar Radiation Data Handbook (ASRDH, 2006) and team leader for developing the current Australian Climate Data Bank (ACDB, 2008), the basis of all building and energy system simulation programs in current use in Australia. Subsequently, he worked on a project for the then Australian Greenhouse Office to project the impact on the built environment of "inevitable climate change".

His interests include solar energy applications and ethical investment and, in pursuit of these, he has served as the Chairman of the Australian and New Zealand Solar Energy Society (ANZSES) and as a director of the Sustainable Energy Industry Association (forerunner of the Clean Energy Council (CEC)) and of the Canberra-based funds manager Australian Ethical Investment Ltd.