The effects of climate change and the rising costs of electricity are key drivers behind the need to improve building energy efficiency in Australia. This need is particularly acute for remote businesses and communities, where energy costs are high, incomes are relatively low, maintenance services are difficult to access, and buildings must cope with extreme climates.

Forming part of an ongoing CRC-REP study into energy efficiency in remote Australia, this paper summarises the findings and recommendations reported in Comfort and electricity use in remote Australian buildings. For this, we surveyed the electricity consumption and construction design of eight community enterprise buildings, three in central Australia (CA: arid climate), and five in far north Queensland (FNQ: tropical climate). Data logging ran from June 2015 to April 2016.

From late autumn to early spring, high building temperatures impact and restrict the available work hours, particularly where there is no air-conditioning. Internal temperatures were compounded by:

- Radiative heating from roofs without low emissivity sheeting or insulation
- Waste heat from office equipment co-located with people
- Thermal leakage through windows.

As per capita consumption of electricity in work spaces was generally low compared with city buildings, it suggests building design and appliance operating protocols provide the best opportunities for improvements.

Critical changes to building design and construction and appliance selection, rather than to human behavior, would give the most energy savings in the buildings studied.

Simple construction adaptations can deliver significant building energy efficiency improvements in remote Australia.

AccuRate can be adapted for assessing thermally efficient enterprise buildings in the hot arid and hot humid climate zones in remote Australia by incorporating the following capabilities:

- An algorithm to measure the impact of forced ventilation
- User input of thermal load parameters to account for occupancy and equipment
- User input of local records for the external environment temperature.

Across two climate zones, hot arid and hot wet, and two construction types, steel frame and breeze block, our study revealed several key opportunities for improvements to thermal efficiency.

One series of measurements was on the impact of external shade or low emissivity foil in reducing the heat radiated into buildings. In steel-framed buildings with no ceiling or insulation, we observed roof temperatures of 60°C.
or greater, although the outside air temperature was no greater than 32°C. This often meant it could be up to 10°C warmer inside than outside. However, shade from trees and shrubs, or the use of low emissivity foil under the roof, reduces the radiant temperature by about 10°C in our study (figures at left).

The reflective foil insulation goes under the roof, with a small air gap between the roof and the foil and the shiny side of the foil facing down to the floor. The foil might get quite warm, but it won’t radiate much of that heat into the building.

**Insulation and sealed buildings in hot climates**

A major opportunity to reduce heat consumption in buildings in remote Australia is to improve the energy efficiency of air conditioned buildings by installing insulation in roofs with ceilings and low emissivity foil in roofs without ceilings and to control drafts to reduce the loss of cold air and profit from natural ventilation when possible.

Using a modified version of AccuRate, we assessed the impact of insulation and the reduction of uncontrolled drafts for each building type.

Taking one building (FNQ1), AccuRate assessments suggested that adding insulation and sealing drafts would improve a star rating from 0.3 to 4.5 for steel frame buildings and from 3.6 to 5.3 for concrete block buildings.

The need for ventilation that can be used with air conditioning is less well understood: this is using ventilation when the air conditioner is turned off (e.g. at night) to remove the heat build-up that occurs in high thermal mass, well-sealed and insulated rooms. The amount of this build-up can be seen in the difference between internal and ambient external temperatures at night.

The figure above shows the potential for using night ventilation in hot arid climates. It may also be useful in humid climates, but the ventilation will need to be controlled by humidistats and temperature sensors to protect the building from condensation and consequent mould or mildew. The impact of such ventilation in tropical climates would benefit from further research.

**Reducing the electricity consumption by appliances, particularly standby consumption**

Over the study period, electricity consumption was two to three times greater in FNQ than in CA. We attribute this to the FNQ enterprises i) running air-conditioning 24 hours a day to preserve artworks, and ii) using more power outlets for their diverse office and studio equipment.
Overnight electricity consumption in two FNQ art centres was approximately the same as during business hours. This could be intentional (e.g. alarms, air-conditioning), unintentional (e.g. equipment left on or in standby), or optional (e.g. running a computer server to maintain a website rather than using an internet service provider).

To determine whether out of hours power use was due to intermittent appliance use or standby mode, we plotted consumption and the duration of operational cycles versus operating power.

The figures to the left compare two, single-split air conditioners in the same studio. The position of the blue bar along the horizontal axis indicates the power (kW) at which electricity was consumed; the blue bar height indicates the amount of electricity (kWh) consumed at any given power; the height of the orange continuous line at each bar indicates the number of hours that appliances operated at a given power. Air conditioner 2 has consumed almost as much in standby as when running, and 10 times more in standby than Air conditioner 1.

By applying this measurement method to appliances on each subcircuit, we could determine the reasons for power consumption outside working hours and suggest ways to reduce it.

The table to the left shows the result of this kind of analysis. There is potential in FNQ to save up to approximately 7 MWhs of electricity each year, and secondary savings could be gained from the reduced thermal load on air conditioners, due to eliminating unnecessary waste heat. This saving would equate to about 7.4 t CO$_2$-$e$ and $2000$ dollars per year. The savings in CA were relatively modest, being about one-tenth of those for FNQ.

### Adapting AccuRate for use in arid and tropical remote communities

AccuRate is a measurement standard used by government agencies, builders and architects to rate the thermal energy efficiency of buildings as part of the Nationwide House Energy Rating Scheme.

We explored whether AccuRate could be (i) used to assess potential energy efficiency improvements to the enterprise buildings, and (ii) adapted to be a readily usable design tool for buildings in remote locations.

Key barriers were i) the lack of a temperature profile for the local environment, ii) the need to compensate for waste heat from commercial equipment, and iii) the need to account for the forced ventilation that is a key factor in the design of thermally efficient buildings in northern Australia.

In four of the six buildings using air conditioning appliances, we compared AccuRate estimates for electricity consumption with measured values. Temperatures outside the buildings were 2–5°C warmer than the values used by AccuRate, which are based on long-term averages at remote locations. We estimated that the error between the AccuRate and measured values of differential temperature between the inside and the outside of the buildings, as well as the impact of waste heat, reflected the error in thermal load.

The study indicated that AccuRate could be a useful tool for the design and assessment of thermally efficient enterprise buildings in remote Australia provided there was a mechanism for i) assessing the efficacy of forced ventilation; ii) user input of estimated waste heat from appliances; and iii) user input of ambient temperature near the building.
Summary and recommendations

This study showed that upgrading the design and construction of enterprise buildings and their appliances would provide energy savings of up to 40% by:

- reducing the need for appliances to run or be on standby 24 hours/day
- isolating or eliminating appliance heat waste
- reducing uncontrolled drafts and using controlled forced ventilation, subject to temperature and humidity control, outside working hours in buildings with high thermal mass
- insulating ceilings and walls where possible
- putting low thermal emissivity foil insulation under roofs in buildings with no ceiling
- planting trees and shrubs to provide shade and transpiration cooling
- replacing sunlights with low solar heat gain units or high insulation translucent cellular or honeycomb polycarbonate units.
- using automated controllers to switch off appliances where appropriate and when purchasing new appliances care should be taken to consider standby power requirements as well as energy star rating
- exploring alternatives where appliances run 24 hours/day, e.g. switch to using an internet service provider instead of maintaining a computer server on-site; or utilise a communication service provider rather than a private branch exchange.

By implementing these measures, enterprises would not only achieve energy cost savings, and have a positive impact on CO₂ emissions, but by reducing workplace temperatures, could increase the number of work days available to employees and clients alike.


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