MODELLING AS AN ACCURATE INDICATOR OF EXEMPLARY BUILDING PERFORMANCE – THREE AUSTRALIAN CASE STUDIES

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ABSTRACT

The paper presents three case studies of simulations undertaken for existing buildings. The buildings are located in three major Australian capital cities. They have all been assessed under the Australian NABERS scheme and are of exemplary performance. In all cases a major refurbishment has taken place with the aim of achieving a targeted NABERS rating. The simulations were undertaken for a variety of reasons and the absolute energy predictions taken from the simulation are shown to align very closely with the measured consumption, in spite of no calibration being undertaken in two of the models. The use of simulation in both design and problem resolution is illustrated.

INTRODUCTION

This paper has been written to illustrate how simulation is able to accurately predict the absolute energy consumption office buildings. It is noted that simulation often under predicts energy use for simulated systems as the model assumes that all systems are operating correctly, which rarely happens in real life. However, the buildings examined below have all been independently shown to have very low energy consumption closely matching the simulation predictions. Furthermore, each of the simulations was commissioned for a different reason and had a different practical outcome. The methodology used in each case also varied.

The buildings are all in Australia but in different capital cities. They comprise the Brisbane Transit Centre in Brisbane, Queensland, the Jessie Street Centre in Parramatta in Western Sydney, NSW and ANZAC Park West in Canberra, ACT. These building have all been assessed under the Australian National Built Environment Rating Scheme (NABERS 2013), which gives an independent assessment of their performance. A NABERS assessment provides a consistent method of measurement for energy consumption based on utility bills as well as providing comparative performance based on benchmarked parameters. A NABERS assessment is given as a star rating from 0 to 6 stars. The final star rating is based on normalised greenhouse gas emissions and therefore megajoules of gas is assessed differently to megajoules of electricity. For simplicity in this paper we only refer to energy consumption.

NABERS separately assesses the base building which under the control of the landlord, or the tenancy, or the whole building. Unless otherwise stated we will be considering the base building operation. The base building provides all the HVAC services, apart from supplementary units although these are supplied by a base building tenant condenser loop. The lifts, common area lighting and exhaust fans also make up base building load. Conveniently, the base building consumption is dominated by loads that are actively simulated rather than being assumed.

Details of the buildings are given below together with the reasons why we were employed to carry out the modelling. We then look at some of the techniques used to ensure that the modelling was accurate and then examine the breakdown of energy used within the buildings. The actions of the building owners and managers post modelling are also presented.

THE BUILDINGS

Brisbane Transit Centre

This 26 year old complex comprises two towers in the middle of Brisbane. This report only concerns the western tower. It has an area of 18,000 m^2 over 8 office floors.

The Centre had never had a NABERS assessment so its performance was unknown. The modelling was undertaken to test a number of upgrade options and ascertain the most effective to implement. However, it had been decided that the chillers were to be replaced and therefore all modelling included efficient chillers.

The Jessie Street Centre

The Jessie Street Centre named after Jessie Street, an aboriginal activist, is located in Parramatta in western Sydney. It was built in 1987 and comprises 20 floors of area 54,000 m^2.

The building had just had extensive renovations when we were engaged to carry out modelling. The building was targeting 5 stars under the Green Building Council of Australia's (GBCA) rating tool for offices. Even for an As Built rating - completed post construction - a thermal model is required for the submission, partly because the GBCA requires a number of defaults to be used in the simulation. The building had been given a NABERS rating of 5 stars but this was deemed unacceptable, and the modelling carried out up that time only showed the building performing at 4.5 stars. We therefore had the interesting task of modelling a building that was known to be working very well and match this with a simulation.

ANZAC Park West

ANZAC Park West is a prominent building in Canberra. It is L shaped with an area of 15,000 m^2 over 5 floors and was built in the mid-1960s. ANZAC Park West was refurbished in 2006 and a new tenant found after 7 years of vacancy. As the sole tenant is a government organisation, Government policy requires the whole building performance to be at least 4.5 stars under NABERS (Energy Efficiency in Government Operations 2013). A NABERS rating for this building had not been carried out and there was concern that the building would not meet its target. Since the whole building combines the tenancy and the base building the landlord was interested to understand the split between performance of systems within their jurisdiction; consequently ratings of the base building and tenancy were also carried out. The base building rating is reported here.

Rationale Summary

These three buildings were modelled for quite different reasons. The first was to establish the best design for an upgrade, the second was to produce a report for the purposes of obtaining a 'green' certification even though the building was known to working well, and the last one was to investigate a possible unknown problem.

SIMULATION APPROACH

Our modelling experience is that it is often much harder to simulate an old building than one not yet built but in the design stage, due to the likely absence of much of the required documentation available. Visiting the building can elucidate the motor sizes on pumps and fans, and careful analysis of the building Management System can throw light on operation. However, the construction of the walls, and the glazing used, is often hard to identify. Key parameters such as pump and fan operating pressures are often not readily available. As fan pressure and turndown curves are very important to have correct in a model we assiduously track down this information. If possible the commissioning results are used when available.

On the positive side occupancy patterns and equipment loads can be ascertained through inspection. We have also been able to use submetering data to help calibrate our model and establish non-HVAC loads although even here serious difficulties are likely. The problems inherent in calibration have been explored in a previous paper by the authors (Taylor et al - 2011)

SIMULATION FINDINGS AND OBSERVATIONS

Brisbane Transit Centre

The Brisbane Transit Centre HVAC system comprises two AHUs per floor serving east and west zones respectively. A VAV system was served by the AHUs. Damper control was used to modulate air supply to the zone VAVs. Heating is from electric terminal reheat. DOE2.1e was used for the simulation.

In addition to the proposed chiller upgrade, the following measures were assessed:

- The inner pane of façade glass is openable to allow access to the interstitial blind and so retrofitting a thin spectrally selective (low-e) film on the inside of the outer pane was possible.
- Improved AHU air flow through variable speed drive was also available as an energy savings measure.
- Alternative control configurations[1] were also considered.

These options and others were examined (Figure 1) and the energy results converted to fractions of a NABERS star for the building (Figure 2). The solar film has almost a half star benefit, which is comparable to having a very wide deadband and proportional control bands for the zones. VAV turndown ability was also clearly a very important factor.

Final modelling was undertaken to test the expected performance with the new chillers as installed, the window film, AHUs with variable speed drive and a new BMS for good control.

A breakdown of the results is shown in Figure 3. The total electrical use was predicted to be 261 MJ/m^2. The modelling results appeared too good to be true, suggesting that the building was capable of achieving a 5 stars NABERS rating. However, when a rating was carried out the result was indeed 5 stars

[1] The effect of control on simulations is reported elsewhere in this conference (Zhang 2013)

with an energy use based on the utility bills of 299 MJ/m^2, only 15% higher than the uncalibrated simulation result. This was even more remarkable as the rating was achieved in the first year of the new occupancy. Based on the modelling it is hoped that a monitoring and verification program will be put in place for the building in the near future and further building tuning will be possible.

Jessie Street Centre

The Jessie Street Centre is another VAV building. However, unlike the Brisbane Transit Centre it has central AHUs located on plant room levels that service centre and perimeter zones. Efficient chillers and new cooling coils were able to provide low temperature (10^{o}C) supply air. Extra duct insulation was added. Many of the modelling parameters were taken from commissioning results although since the simulation was for Green Star the Green Star defaults for occupancy and loads were used. The software employed was Tas 8.5.

No alternative scenarios were required and a breakdown of the energy use in given in Figure 4 and Figure 5. The combined annual energy intensity of the gas and the electricity is 233 MJ/m^2. This simulation is well into the NABERS 5 star band. The actual NABERS assessment was 266 MJ/m^2, again only 15% higher than the uncalibrated simulation estimate. An estimate of the energy use before refurbishment was 557 MJ/m^2 (Veitch 2009) so the upgrade has reduced energy consumption by 52%.

ANZAC Park West

The ANZAC Park West building in Canberra is similar in HVAC design to the Jessie Street Centre with centralised AHUs and a VAV system. However, air cooled chillers are used and a less efficient tenant condenser water loop is used as closed circuit cooling towers are employed.

Sub-metering data was available to confirm the accuracy of the modelling although care had to be used when calibrating as the modelling software weather file did not match the actual weather (Taylor et al 2011). Extensive observations were made on this building as a NABERS tenancy rating was carried out and therefore a survey of equipment was undertaken and a profile of actual occupancy established. The software used was IES <VE>.

The results are shown for electrical consumption in Figure 6 and there is a further 182.1 MJ/m^2 for gas consumption giving a total of 364.5 MJ/m^2. The NABERS base building rating at gave a value of 378MJ/m^2.

The sub-meters allowed comparison between HVAC consumption as measured and as simulated. The metered energy in 2011 for the chillers and pumps was 35 MJ/m^2 and simulated 31 MJ/m^2. However, the recorded AHU fan usage was below that simulated. This issue was resolved when site examination showed a consistent under-reading in one of the meters.

Besides the faulty meter the analysis also showed up a larger than expected consumption on the house risers. This is apparent in Figure 6. Inspection of meter readings showed that this was most likely caused by equipment running out of hours and is one of the main findings of a study that was intended to detect faulty operation. Correction of this fault would most likely result in a 5 star rating for the building.

A further known fault is an under-heating problem for the ground floors during the wintertime. No reheat is installed in the building. Winter mornings in Canberra can be as cool as -8^{o}C. On-site measurements were taken of AHU supply air temperatures which were found to be only reaching 25^{o}C. It should be noted that the ground floor is above an unairconditioned basement area or sub floor area and there is poor sub floor insulation if any.

Examination of modelling output concurred with the on-site findings. Figure 7 shows the AHU supply air temperature, zone temperature and outside air temperature for a cold winter's day. Figure 8 shows the temperature of the zones stacked vertically through the building supplied by the same AHU. The supply air temperature is being driven in the model by the high select temperature of the zones and all floors above the ground are comfortable. The supply air temperature is satisfactory for the upper levels but clearly too low for the ground level.

A solution for the ground floor would be to install reheat. However, the effect of the passive solution of adding insulation to R 3 m^{2}K/W was investigated and results in a 1.5^{0}C rise in ground floor temperature (Figure 9).

ANALYSIS

The consumption of the AHUs varied from 34 MJ/m^2 for the low temperature VAV supply for the Jessie Street Centre, to approximately 70 MJ/m^2 for the other two buildings. We note that in the Jessie Street Centre the previous Green Star modelling that was deemed unacceptable the fan energy was reported at 120 MJ/m^2. The turndown for the fans was not described. The result is almost four times larger than our result. This comparison underscores the necessity of ensuring that the AHU fans are simulated at the correct pressures and with the correct fan curve.

In Australia cooling is a significant part of energy consumption, typically of similar magnitude to the fan energy. The climate in Brisbane would be expected to require more cooling energy than Sydney or Canberra and this is borne out by the chiller energy reported. The combined chillers, cooling towers and pumps for the Brisbane Transit Centre gave a consumption of 118 MJ/m^2, for the Sydney building consumption was 64 MJ/m^2, and for Canberra, which had air cooled chillers, only 31 MJ/m^2 was simulated. The cooling season in Canberra is relatively short and economy cycle is often available. It might be expected that the Transit Centre could reduce its consumption provided if less reheat was able to be used.

In an absolute analysis non HVAC plant requires careful consideration. In the first two simulations the lift energy used was based on the NABERS default of 28.8 MJ/m^2 per annum. However, we have developed a formula based on empirical observations that allows lift energy to be established with greater precision (Bannister et al 2011). Some of the parameters considered are lift drive type and the number of floors serviced. The lift energy in ANZAC Park West was established from the metering and was 9.5 MJ/m^2 which is much less than the NABERS default. Given the move towards high performing buildings estimating the energy used accurately by the lifts becomes a crucial step in the modelling.

The tenant condenser water loop is now considered. In ANZAC Park West the energy to produce the supplementary circulating water was metered at 11 MJ/m^2. Closed circuit towers are used. The Jessie Street Centre is much less and was calculated to be 3 MJ/m^2. The calculation was based on the NABERS default which is that the loop runs at 50% capacity during business hours and 20% otherwise. The key assumption in the calculation is the turndown on the pumps. In this case an x^2 turndown was used. The similar result for the Brisbane Transit Centre gave 4 MJ/m^2 again based on the size and operation of the installed pumps.

Whilst other non-HAVC equipment such as common area lights, carpark lights and exhaust fans are reasonably straight forward to model and have been included in the analysis figures, it is worth noting the generator heating for ANZAC Park West. The consumption was metered at 14.5 MJ/m^2 and is caused by sump heaters running continuously in the large diesel generators.

CONCLUSIONS

With attention to input parameters and control it is possible to accurately simulate the absolute energy consumption of a high performance building. The results indicate that the simulated performance, which is typically taken to be above that possible in real life, can indeed be achieved as we have shown to an accuracy of 15% or better.

As is often the case simulation is a very useful design tool, but simulation of actual buildings can provide useful insights into problems and offer quantified solutions as well.

ACKNOWLEDGEMENT

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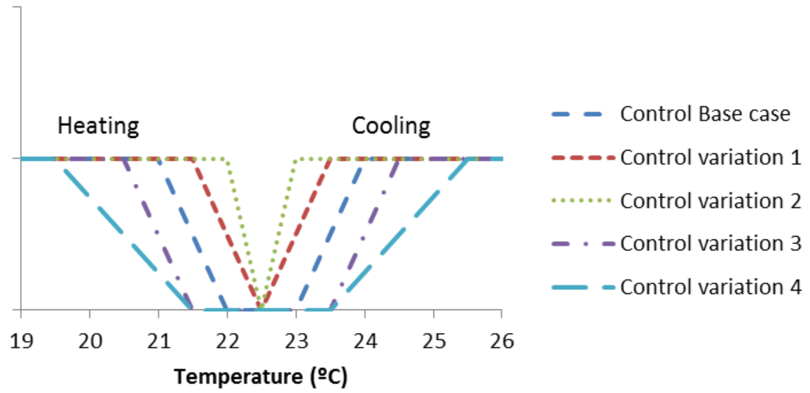

Figure 1: Brisbane Transit Centre Control variations tested

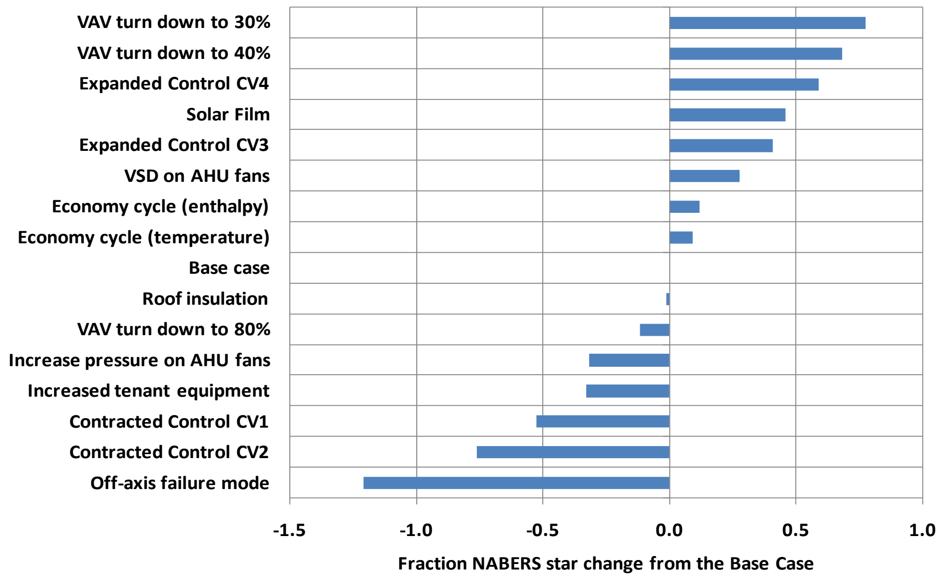

Figure 2: Brisbane Transit Centres Summary of modelling results

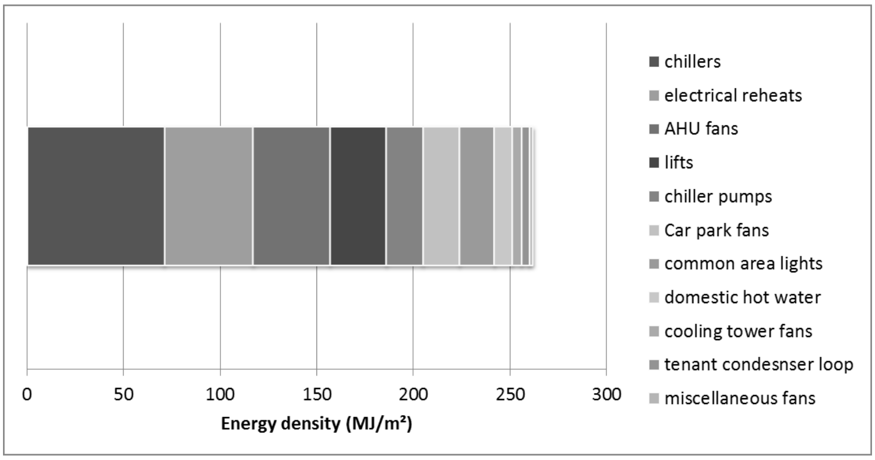

Figure 3: Brisbane Transit Centre Final modelling results

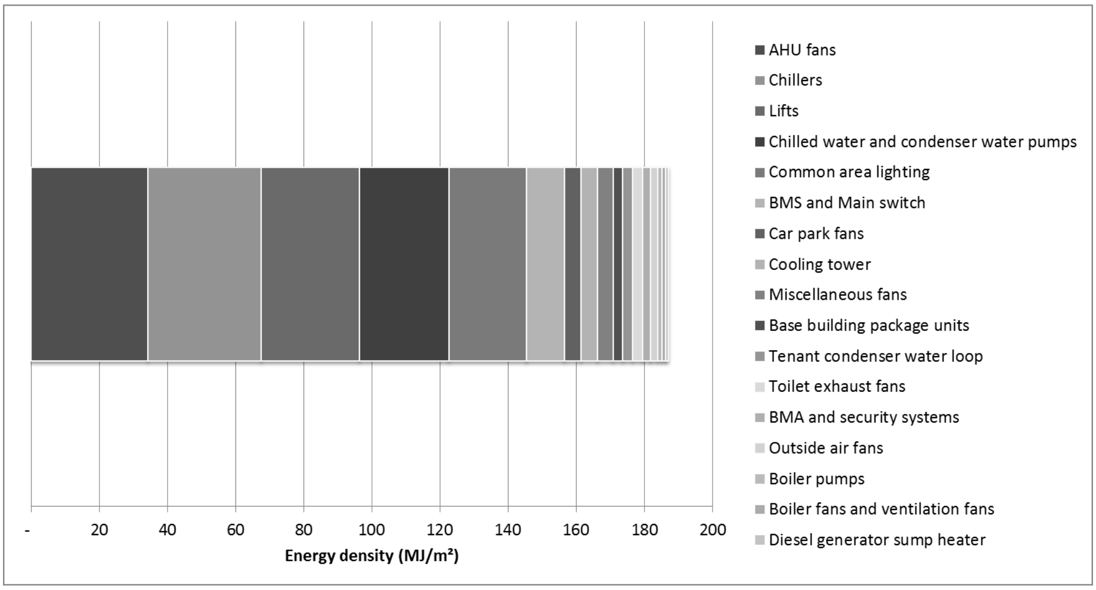

Figure 4: Jessie Street Centre modelling results - electricity

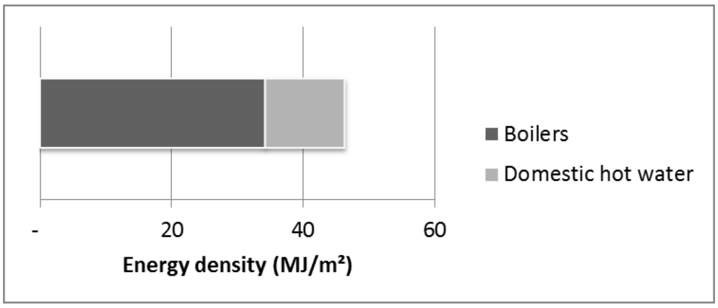

Figure 5: Jessie Street Centre modelling results - gas

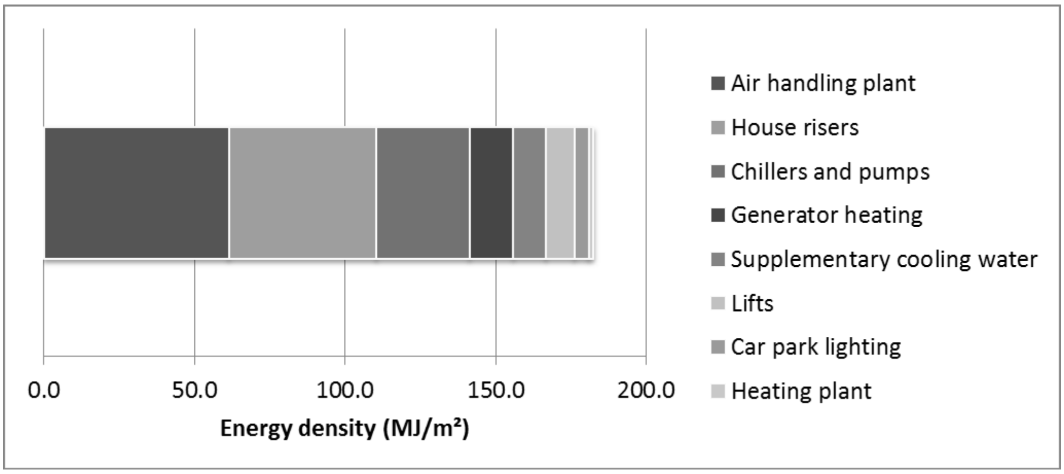

Figure 6: ANZAC Park West modelling results electricity.

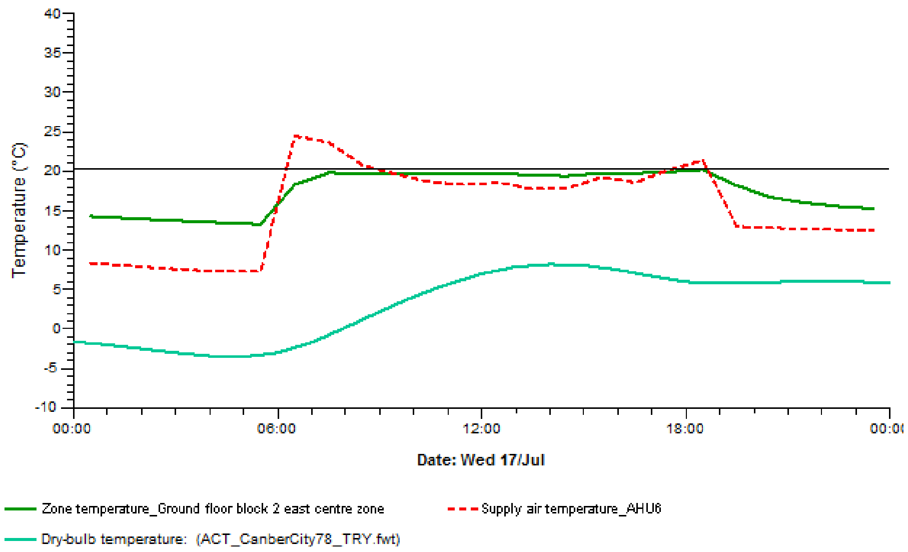

Figure 7: ANZAC Park West ground floor temperature, supply air temperature and outside air temperature for a day in winter (17th July) taken from the IES weather file.

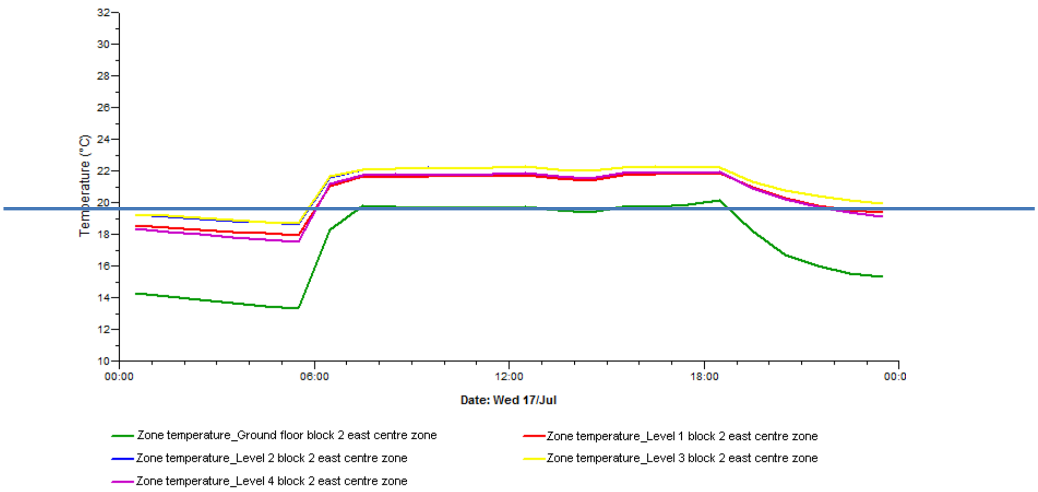

Figure 8: ANZAC Park West zone temperatures for all levels in the building served by a single AHU for 17th July taken from the IES weather file.

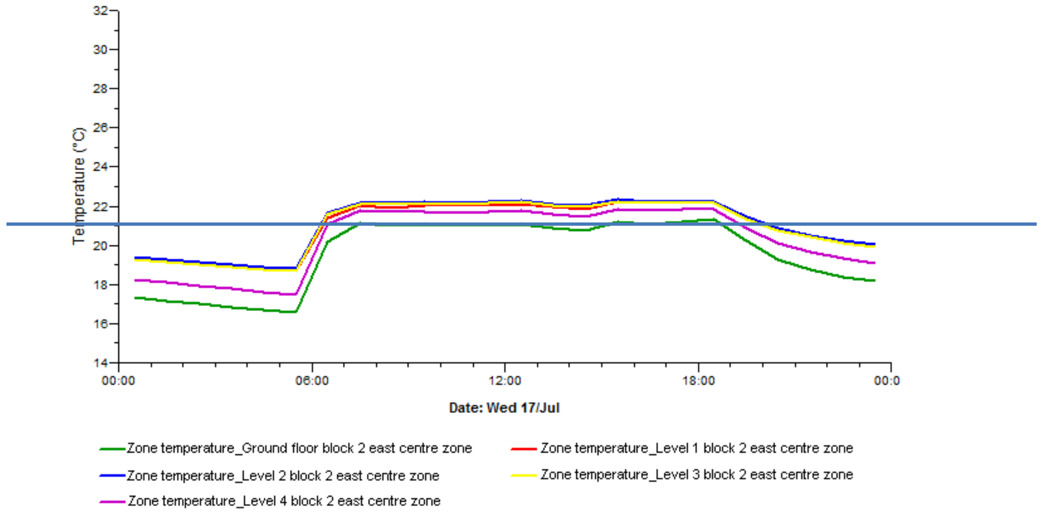

Figure 9: The same graph as above but with R3 m^2K/W insulation added below the ground floor slab