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Practical modelling application – ICC Sydney

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ABSTRACT

The new Sydney International Conference Exhibition and Entertainment Precinct (SICEEP) Sydney is an Au$1.5 billion development at the heart the Sydney Harbour waterfront precinct, a vibrant public domain on Darling Harbour. Part of the development and operation of the new facility is the requirements for energy management, modelling and metering to provide a world-class facility that is also a highly energy efficient. To ensure the energy performance of the facility, a design energy benchmarking model was built and energy targets set for electricity and gas consumption. Metering and energy management of the facility are provided to allow the onsite Energy & ESD manager to keep energy consumption below the target values.

During the construction and initial operational period, a second energy model was built using operational data from the site. Early calibration of the energy model has occurred and is used to help determine possible energy savings available. The information is used to help the facilities management team to target specific operational strategies to meet the benchmark targets while meeting the very stringent thermal comfort conditions of the facility.

This paper will examine the process, application and issues of using a theoretical model, construction data and actual performance data when managing the energy use within a facility. Particular aspects of the process will be examined that address building the operational energy model, determining and co-ordinating with the construction program, and construction information. The issues associated with access to end-user information that impact on the delivery of the IES-VE model and operational strategies are also examined.

INTRODUCTION

The new Sydney International Conference Exhibition and Entertainment Precinct (SICEEP) houses the International Convention Centre (ICC) Sydney at the heart the Sydney Harbour waterfront precinct, set among restaurants, retail and a vibrant public domain on Darling Harbour. Sitting at the heart of a broader Au$3.4 billion revitalisation of Darling Harbour, ICC Sydney is an Au$1.5 billion development that is adjoined by the new 590-room luxury hotel, Sofitel Darling Harbour, and a new residential and commercial development. A new pedestrian boulevard connects the waterfront back to Central Station and laneways to further activate this site.

Part of the development and operation of the new facility is the requirements for energy management, modelling and metering to provide a world-class facility that is also a highly energy efficient group of buildings. The site is home to the first community-funded solar energy project of its kind in Australia. One of Australia's largest solar arrays within a central business district is on the roof of the Convention and Theatre buildings to generate power to be exclusively used within the new venue. Members of the public can buy shares in the social venture that will own the solar array, Sydney Renewable Power Company.

The SICEEP project is a public private partnership arrangement between Infrastructure New South Wales (iNSW), Lendlease (LL) and Spotless. Each of the groups provided input throughout the design and construction phases of the project to ensure the facility could meet the design brief requirements and become an outstanding, internationally recognised, public facility within the heart of Sydney.

iNSW is the New South Wales government department that led the delivery of the new facilities, having developed a PPP tailored for the project.

The use of energy modelling is typically restricted to the design stages of projects and very little emphasis is applied to the development of an "Operational Energy Model".

THE ENERGY MODEL

Understanding the limitations and level of effort required to provide a calibrated simulation energy model that is useful in operation is critical for the development and acceptance of building simulation (BS) by the wider facilities management industry and will help transition BS from being a "cottage industry" to being a highly valued industry within the building and construction sectors.

OBJECTIVES

This paper aims to provide the reader with an insight into the work carried out at the SICEEP to deliver an Operational Energy Model that has the potential to be used for the full 25 years of the project. The areas that will be addressed in this paper are the process of building an "Operational Energy

Model"; the data identification and collection process for providing inputs to the model; and the first stages of calibration of the Energy Model for practical use on site and during the entire lifetime of the PPP contract.

PROVIDING AN OPERATIONAL ENERGY MODEL

Background

From the mid-1970s, with the increase in computer power, simulation modelling has emerged to help designers make better informed decisions within many industries. The ability to simulate scenarios and assess the results against real-life performance has improved the abilities of designers to the extent where the current expectation is "things will work" first time, every time.

In the construction industry, BS has been primarily used throughout the design process from concept to construction and mainly for verification of peak sizing and peak operating conditions. There have been several studies that have highlighted the discrepancies between simulated building energy performance and measured performance. (Claridge, 2011), (Emily, Ryan, & Sanquist, 2012), (Dall'O", Sarto, Sanna, & Martucci, 2012) To achieve an operational model that produces results similar to measured values is currently very time consuming. The quantum of input data, the accuracies and capabilities of the modelling software, and the timely access to available data make the process very difficult without support of the owner or operator of the building.

"The modeling process does not represent an easy task, even for building simulation that does not require calibration. Calibrated simulation (CS) models are far more complicated and require higher expenses than "uncalibrated" models." (Enrico & Valentina, 2015) A calibrated model can take many steps to achieve and the below table outlines these steps.

Calibration levels	Utility bills	As-built data	Site visit/ inspection	Detailed audit	Short-term monitoring	Long-term monitoring
1	X	X				
2	X	X	X			
3	X	X	X	X		
4	X	X	X	X	X	
5	X	X	X	X	X	X

Table 1: Calibration Levels based on building information available (Enrico & Valentina, 2015).

CS has been officially endorsed by the International Performance Measurements and Verification protocol (IPMVP). The use of simulation is endorsed through the IPMVP by the detailed Option D approach to energy efficiency verification. Option D in IPMVP provides for hourly or monthly data to be used for verification of the modelled performance against the measured performance, when developing Energy Performance Contracts. IPMVP is endorsed by the Office of Environment and Heritage (OEH) as part of the Energy Efficiency Scheme (EES). Independent Pricing and Regulatory Tribunal (iPART) administer the creation of Energy Savings Certificates (ESCs) and endorse the use of the IPMVP and option D, calibrated simulation.

The Operational Energy Model built for the SICEEP has been done with the goal of achieving the requirements as outlined in the IPMVP. This will allow for the model to be used effectively in the development of Energy Conservation Measures (ECMs) for the duration of the 25-year FM contract.

The modelling process for SICEEP

For this project modelling has been used throughout the early design and contract initiation phases and then again during the final construction and operational phases. The use of the models is for different purposes within the whole project timeframes and hence two major models were built. The first model was built (by Energetics) as part of the establishment phase. This first model determined the energy targets for electricity and gas consumption that are used to build the contract target values.

The first model is based on assumptions and design concepts that formed the project design brief and was based on analysis of concept design drawings. In building this model actual operational data, equipment information and operational profiles where not available, therefore standardised data from the design assumptions where used.

Design information as used in the engineering sizing and equipment selection processes was used in the model for services and equipment. Additional data was gathered from the operation of the existing facility. This was used to in the assessment of the energy consumption used for typical events. Safety factors were applied, and the model used some diversity applied to full-load operation for most equipment.

The impact of weather has been investigated and included here for completeness. What was analysed was the relationship between Cooling Degree Days (CDD) and Heating Degree Days (HDD) on the overall energy consumed by the base load. It was found that the R2 between electricity and CDD is 0.92 and between gas and HDD is 0.95. (R2 needs to be greater than 0.75 to indicate a good correlation between the two sets of data). Reviewing this with two years of actual Sydney weather data only had a minor impact (~3%) on the overall electricity consumption. There is no assessment of the impact of weather on gas consumption.

Energetics ran the existing daily energy used by the existing SCEC against the number of attendees data provided through a regression analysis to find the degree of correlation. The R2 is 0.135, which indicates a low correlation between the number of people attending and the daily energy use.

The first model is an "uncalibrated" model, because no building information was available at the time, i.e., the model is purely a 'design' based BS model.

The Operational Energy Model used "as built" drawings, actual equipment data from the asset register, O&M manual, and operational profiles from the FM team and the inputs to the BMS system. The Operational Model is undergoing calibration, with the integration of BMS output data being used to redefine the profiles and provide better estimates of consumption data. There are over 60,000 FFE items in the facilities and 90,000 hard assets. Approximately 30,000 of the hard assets are services assets that consume energy. All these assets have been entered into the Operational Energy Model.

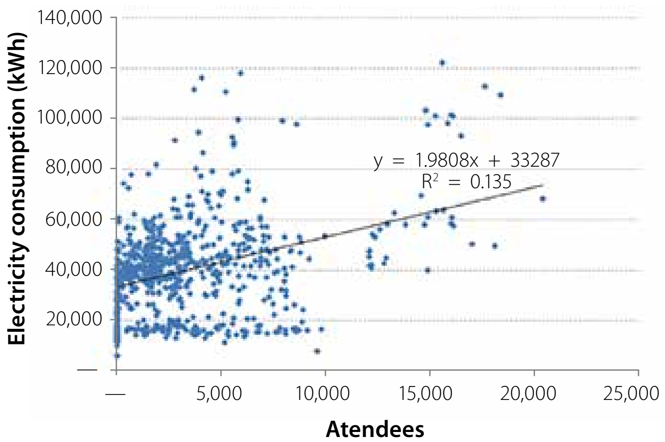

Figure 1: Correlation between attendees and electricity consumption.

As part of the process of building the Operational Energy Model a metering and electrical review was conducted. The idea behind the metering review was to provide an assessment of the metering and BMS system to match the requirements of the building simulation modelling and the operation of the functional spaces. The metering design was based on meeting the requirements of BCA Section J and the LEED rating for the site. The functional spaces, operation of functional areas, and interaction with the pre-function areas were not the basis of the metering design.

The Operational Energy Model is a Level 3–4 Calibrated Simulation (CS) as outlined in Table 1. Calibration Levels based on building information available. At the time of writing this paper, the data inputs are to the stage of Level 3. However, further work on the model is occurring and will approach the Level 4 criteria by the end of 2017.

Analysing the processes

The process of using BS for the determination of contractual energy targets as part of a full 25-year PPP is relatively new, and there has been little detailed analysis of the process, models or outcomes. The first comparison considered is the modelled areas. Modelled areas and actual building areas will not usually match, and this can have an impact on the applicability of the predicted values.

The SICEEP design and construction process is typical for all buildings, and demonstrates the changes that occur during the development process. Typical building area changes occur due to requests from the end user, construction limitations only found during the construction process, architectural reviews during construction, and site limitations, among other drivers. The following Table 1 – Area comparisons, shows the differences between the Energetics pre-design areas, architectural design areas for the basis of the construction, and the final areas of the building from the “as built” drawings.

Although the “total area” figures indicate a high level of consistency between the design and the modelled areas, the individual areas, in particular the carparks and Entertainment Centre, show significant differences, and these impacts on the end-use breakdown of energy consumption. The areas of the models affect the W/m2 inputs for lighting, equipment, occupants and the ratios of facade to floor areas. The target values determined by each model will therefore vary.

Comparison of the modelled areas to the design building areas. Modelled areas are based on “As Built” drawings received during final construction.

Area	Modelled GFA m²	Design GFA m²	Model/ Design %	Energetics model areas m²
Sydney International Convention Centre	76,451	78,485	97%	42,500
ICC Exhibition Centre	70,156	68,236	103%	61,700
Entertainment centre (theatre)	27,182	34,602	79%	26,900
Total building area	173,789	181,323	96%	131,100
Exhibition carpark	29,203	25,200	116%	
Theatre carpark	14,660	10,700	137%	
Total carpark area	43,863	35,900	122%	45,000
Total area	217,652	217,223	100.20%	

Table 2: Area comparisons.

Within the PPP project the FM is required to achieve a targeted level of energy efficiency for the consumption of electricity and gas. Energetics provided this scope of works and set the benchmark values that the facility managers are required to achieve during the full 25-year life of PPP contract.

The Energetics modelled values, the contractual target values and the Operational Energy Model values are presented in Figure 1: Predicted monthly electricity values. Actual volumes cannot be shown due to confidentiality; however, it is clearly evident the variation in the annual profiles of each set of predicted values. This presents a problem when trying to calibrate a model, as there are significant differences in the predictions from each simulation.

The difference between each set of modelled values for this project is due to many factors outside the control of the modellers. The contractual values are set as part of the contractual negotiations and are within that process. The Energetics model was used as the basis of the contractual values; however, the exact detail of why they are so different was outside the scope of influence of the modellers. The Operational Energy Model that is being used to try and provide a calibrated model is based on “as built” and “as installed” data, while the Energetics model has significantly more assumptions.

The BS models for the prediction of the gas consumption are provided in the Figure 2: Predicted monthly gas values. The analysis of the gas consumption highlights even greater variance. The predicted values for the Energetics design model would have been based on very high level assumptions for kitchen equipment and other gas consuming devices. The Operational Energy Model had the benefit of using actual data from product information; however, it is still based on a set of assumptions.

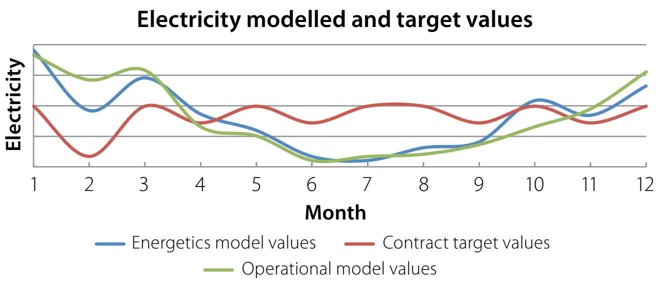

Figure 2: Predicted monthly electricity values.

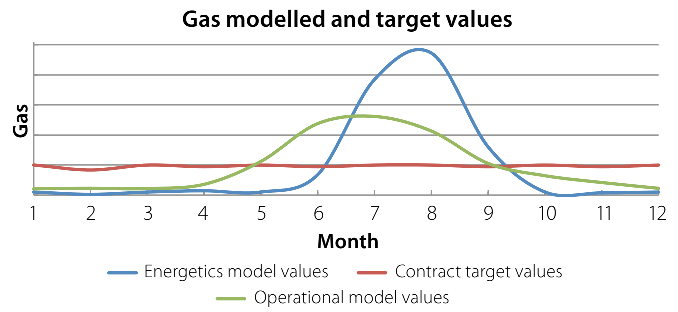

Figure 3: Predicted monthly gas values.

The facilities manager on the site has a contractual obligation to provide an Operational Energy Model that can be used to re-calibrate the initial benchmark (contract target) values provided by the Energetics modelling. Fig 1: Predicted monthly electricity values is a dimensionless graph for comparison of the different outputs from the Energetics and Operational Energy Models. As can be seen in the graph there is definitive variance in the modelling results.

Early calibration of the model

The facility has been running for six months. The actual consumption data available for the site is not sufficient yet to provide a well-calibrated model. The first six months of electrical data is presented in Fig 4: Electrical consumption comparison – actual vs operational. The data indicates a reasonable level of consistency in the comparative performance. The January month was the first operational month for the facility and there were minimal events. The January consumption figures are not considered to be suitable for determination of the consistency between the two data sets, as this is the first fully operational month and many management and control issues were still being sorted.

Gas consumption values are much harder to calibrate. This is due to large amounts of gas use being associated with the kitchen equipment. Future work will focus on understanding the gas consumption profile for the kitchens.

Outcomes and discussing the issues

BS and CS are methods of providing information about the performance of a building. The SICEEP project is a unique case, where contractual obligations, support from the facilities management team and technical capabilities within the appropriate organisations all aligned. Thus, a process was put into place that allowed for the CS to be investigated and the process started. Further development of the CS model will be ongoing, and within the first year of operation it will be possible to achieve the elusive goal of a predictive CS model.

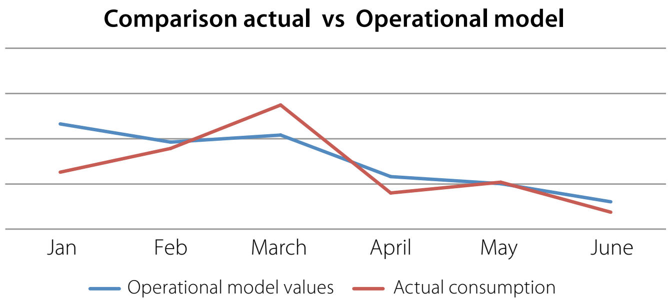

Figure 4: Electrical consumption comparison – actual vs operational.

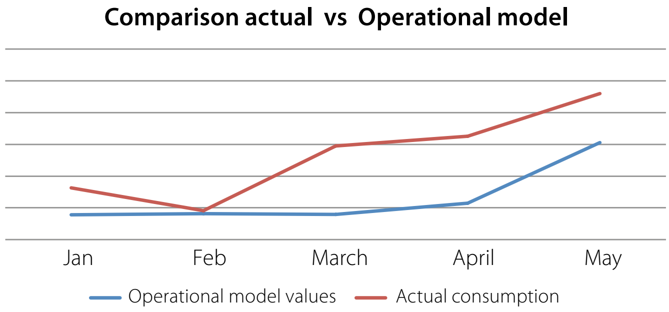

Figure 5: Gas consumption comparison = actual vs operational.

In the SICEEP building simulation there is a strong understanding of the plug loads. The Operational Energy Model appears to behave well with respect to the non-event-related plug loads. The Operational Energy Model is not tracking events well, and the use of air conditioning during events. Where the number of events is low (April) the electricity Operational Energy Model prediction is close to actual, as there is little to no cooling required by the air conditioning. For the months with few events (Feb) and little to no heating required, the gas was close to the predicted. The fixed plug loads for this facility appear to be driving the Operational Model predictions, because they do form a large proportion of the electrical and gas loads.

CONCLUSIONS

The modelling process

It is evident that an early building simulation based on design data, concepts, predicted operational profiles, estimates from existing facilities and assumptions is very useful in the design and estimates of the facilities potential. The results to date indicate all building simulation to date does not provide a high level of confidence in the prediction of electrical and gas energy consumption. The processes used in developing each of the BS models are appropriate, and follow good industry practice given the available information at the time of development.

The metering system review process found the metering is not quite suitable for the effective break-up of electrical and gas consumption to match the BS model. This is because electrical and gas supply is not designed to break out consumption based on functional and operational parameters, but is instead based on BCA section J requirements and the physical limitations of the site and distribution backbone.

To achieve the required outcome of a useable energy model that can predict actual performance and is tuned to the buildings operation is a difficult task that requires a highly committed team, and sufficient expense to cover the workload. It is simply time and money that are the hurdles we need to overcome, and not any technical limitations. We have the power to achieve the required outcomes; now it is just the energy and money that needs to be sorted.

Model analysis and calibration

The Operational Energy Model is a step change away from the actual consumption for the electricity, while the gas appears to be much harder to match the predicted values against the Operational Energy Model values. The analysis to date indicates the Operational Energy Model is following a similar pattern to the actual performance however the actual monthly consumption is currently tracking between 11% and 21% below the Operational Energy Model predictions.

Some operational strategies are used that provide energy savings via detailed control and pre-conditioning of certain spaces, especially the main Sydney Theatre. These strategies can only be captured via the BMS outputs that are then directly feed back into the energy model. This process is under way at the moment.

It is clear the correlation between the HVAC gas and electricity consumption predictions from the Operational Energy Model are not in line with the actual consumptions. Some operational strategies are in place that are in line with the event energy management:

- Using economy mode where possible
- Closely scheduling the air conditioning to match the events
- Active management for energy efficiency of start-up and pre-start of systems prior to events.

It is difficult to input these strategies into the CS model as they chance for each event. From this study additional calibration is required to provide a true energy consumption pattern of event-related services.

To date the calibration process has not been completed; however, some lessons learnt are:

- Using all available technical data of actual equipment is critical
- Understanding the operational uses of the building, allows for the profiles to better match the actual operations.

Once these two items are completed, the next steps are reliant on the available access on the site to both data and personnel. Therefore, forming a strong relationship with the FM is critical, as their co-operation is the key to collecting the required data to calibrate the model. ▮

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