FORUM

Surpassing expectations:

An integrated approach to design, delivery, commissioning and post occupancy evaluation

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1 ABSTRACT

The commercial office building at 66 Waterloo Rd is remarkable in that it reached its "aspirational" performance target of NABERS Energy 4.5 stars (previously ABGR) within 12 months of "normal" operation, and exceeded this requirement to achieve 5 stars within 18 months, by January 2009. It is the first new building asset in the Stockland portfolio that achieved and then exceeded its development targets in such a short time frame.

It is noteworthy that the building design does not pander to any ONE attribute for achieving this high level of performance for reduced greenhouse emissions. For example there are no chilled beam systems, ventilated facades or tri-generation systems installed.

The credit for this achievement is a testament to teamwork and collaboration between all parties, and the use of an integrated process of design, delivery, commissioning and post – occupancy follow-through. This paper will describe the process that was followed, and attempt to collate conclusions useful to industry. This is considered of particular significance given the current debate in the US, UK and indeed in Australia, of divergence between predicted and verified energy/greenhouse performance.

2 BACKGROUND

The development at 66 Waterloo Rd, Macquarie Park is a 10,000 sq m, G + five-floor configuration, rectangular floor plate, commercial office building. Its construction cycle can be considered to be quite typical of this type of development, namely:

- Concept design documentation and a development approval is put into the market by a portfolio property owner, and building companies provide competitive tenders to vie for the right to build and deliver the project
- The selected builder reviews the documentation and makes changes to achieve the same amenity and performance while delivering the project at a lower cost
- There is a 12-month defect liability period after practical completion, and any defects that are identified during that time are rectified by the builder
- At this time, the facility management arm of the owner takes over complete control of maintenance and operation of the building.

Completed development at 66 Waterloo Road, Macquarie Park

66 Waterloo Rd reached its "aspirational" performance target of NABERS Energy 4.5 stars (previously ABGR) within 12 months of "normal" operation, and exceeded this requirement to achieve 5 stars within 18 months, by January 2009. It is the first new building asset in the Stockland portfolio that achieved and then exceeded its development targets in such a short time frame. 66 Waterloo Rd is currently listed on the NABERS Energy website as having achieved this exemplary

level of performance for base building operation without assistance of Green Power. This is equivalent to a reduction of 58 per cent greenhouse gas emissions over the average performance of a 1999 building.

This paper discusses the integrated design, delivery, commissioning and post-occupancy evaluation process that enabled this high level of performance to be achieved in such a short period of time.

3 PROCESS

3.1 DESIGN AND CONSTRUCT STAGE

In late 2005, an ESD consultant became involved in the project on the invitation of the builder to work with the project delivery team and contribute to ESD initiatives.

It was engaged to review the entire building design from an energy-efficiency perspective and develop a view on the ability of the building to achieve a 4 star NABERS Energy rating in operation. A whole building energy model to predict energy/greenhouse performance of 66 Waterloo Rd, and to test options to improve this performance to a 4.5 star NABERS Energy level was also part of the scope.

The starting point for the design review was a set of concept design documentation documents that were about two years old. This original design documentation was developed without regard for a performance target, and when modelled as documented, the building was predicted to have the potential to perform to a theoretical rating of 4.28 stars NABERS Energy. As there is always a difference between theory and practice, it was felt that there was a risk that the original design may not perform to the required 4 star NABERS Energy target.

A number of changes based on the outcomes of the whole building energy simulation study were proposed. The most important changes are listed below:

- The original design had two air-handlers serving four perimeter zones; it was felt that this configuration would impose a large reheat energy penalty. It was agreed to change to a four-perimeter AHU, "face zoned" VAV design. There was an implication on plant room space, which was tight, but the mechanical contractor proposed to overcome this by stacking the AHUs.
- Fan speed control was also proposed on the main AHU fans, with the individual VAV boxes to have very low turndown ratios. This was proposed to be achieved by the use of "induction VAV boxes" (IVAV) and standard room diffusers. IVAV boxes allow the primary air supply from the AHU to be reduced significantly while maintaining close to full design flow at the diffuser outlet.
- A supply air reset strategy was proposed. Electric reheats were originally deleted in the internal zones, and later deleted on all zones.

- As the energy from the foyer air-conditioning would be included within ABGR energy use, it was proposed to use the base building chilled water plant for the foyer AHU, rather than the package plant originally documented. The central plant was deemed to provide chilled water at significantly higher COP.
- High-efficiency screw chillers with minimum COPs of 5.5; a condenser water reset strategy, and VSDs were proposed for the cooling tower fans.
- High-performance double glazing was proposed on all office floors, with SC of 0.3 and U-value of 1.8 (both centre-of-glass values); the height of the glazing was reduced to 1800mm by raising the spandrel sill level to 900mm. This was by far the most contentious of all the changes proposed.
- The lighting loads were reduced to a design LPD of 8.5 W/sq m in the office floors, and lower (actual) loads for car park basements, toilets and the foyer.
- Equipment loads were reduced in the model from a originally proposed 25 W/sq m to 20 W/sq m; while it was felt that the actual loads might be lower, the team was unwilling to go below this value for this project.

All of these changes were discussed and agreed to by the entire design and contracting team in design meetings. The change in glazing height in particular had a major impact on the visual and aesthetic impact on the building. To their credit, while there were several vigorous discussions, every member of the delivery team was keen to achieve the performance goals imposed by the property owner and willingly participated in developing practical solutions to the proposed design changes. This collaborative approach, more than anything else, contributed to the later success of measured performance of 66 Waterloo Road.

During the design and construct stage, the ESD consultant provided three interventions:

- a concept stage energy model analysis, with a series of options to improve performance as described above
- a 50 per cent detailed design model, which began to incorporate contractor equipment selections for lighting, air conditioning and building envelope, and
- a final contract design model that incorporated a significant amount of detail, particularly in terms of air conditioning equipment, e.g., coil sizes, AHU level supply air temperatures and flow rates, individual chiller part-load curves, specific pump heads.

These models were devised with conservative performance assumptions that were tempered with experience and good engineering judgement, so as to give the building the best chance of achieving the predicted performance. The stated intention, at all times, was to deliver a building that was capable of real performance at these levels, rather than meet a design benchmark, e.g., BCA Section-J compliance or ENE-2 compliance for Green Star.

The predicted results from the initial models led to a review of equipment sizes for the HVAC equipment based on the new facade, building envelope and internal load configurations. Equipment sizes were reduced to more appropriate levels from the original design. In the authors' opinion this re-sizing of equipment has resulted in much greater stability in the operation of the HVAC system at 66 Waterloo Road.

3.2 COMMISSIONING AND POST-OCCUPANCY EVALUATION

In late 2007, the ESD consultant met with the building owner and was given the opportunity to work with them to ensure that 66 Waterloo Road did indeed meet the performance targets that were modelled earlier. At this time the building was just being completed, practical completion had happened and the building was being handed over. The sub-contractors had completed system commissioning, and building occupancy was already over 75 per cent.

In accepting the commission, we brought together representatives from the building owner and the builder organisations, and a clear decision was taken by all parties to work in a collaborative fashion to work towards the goal of achieving high performance for 66 Waterloo Road. This was a vitally important step as there was ample possibility for the process to dissolve into a finger pointing and vitriolic dead-end exercise.

There was also a clear decision, agreed to by the owner and the builder, to separate "defects" from "aspirations", with a clearly defined process of handling the two. "Defects" were equipment and processes already outlined in the design and construct documentation that were not installed or not working as documented, and to be paid for from the builder's pocket. "Aspirations" were strategies that might require re-programming or installation of additional equipment, and designed to improve the performance of the building beyond what was already documented. These were "variations", to be paid for by the building owner.

One of the first actions was to advise the building owner in finalising a sub-metering system configuration that was being designed and installed for the building. The authors' efforts were directed at ensuring that the sub-metering system was able to report energy use in the same energy end use categories as the energy modelling exercise.

The second action taken was to review the operation of building systems which had already been commissioned by the various sub-contractors, against the "final contract design" energy modelling report produced at design and construct stage. This could be called a post-occupancy evaluation of the building and its energy sub-systems. The authors relied on experience and the use of the installed BMS systems to carry out this review.

The review indicated that there were gaps in calibration of sensors and inconsistencies in the application of documented control strategies, for example:

- the "chillers in series" sequencing strategy was not working effectively, and there was excessive use of bypass that was causing increased pumping energy use; the chilled water set point was lower than prescribed, leading to chillers working harder and using more energy than predicted, and the condenser water reset strategy was not implemented correctly.
- the enthalpy control economiser cycle was not working correctly; damper operation was not synchronised, static pressure and speed control tracking of AHU fans were not consistent.
- some of the induction VAV boxes were not set up correctly in terms of max/min flow and calibration of temperature and flow sensors.

As the mechanical and control sub-contractors carried out appropriate re-calibration and re-commissioning activities, it rapidly became clear that the building would easily achieve the required "aspirational" 4.5 star NABER Energy performance rating, based on a forward prediction of about six months of energy use data that included the summer season. In fact the building operation improved to about 4.8 stars by the time this activity was completed.

At this point the building owner was approached with a proposal to improve performance of 66 Waterloo Road to beyond 5 star NABERS Energy with a small capital investment. The proposal was immediately accepted and the sustainability and facility management teams from the building owner's side worked with the authors to rapidly achieve this goal.

A series of interventions were carried out as discussed below:

- The sub-metering data revealed that ancillary energy systems were responsible for almost half the base building energy use at 66 Waterloo Rd car park and base building lighting were found to not be adequately controlled and remained energised for long periods of time. Once identified, the facility management team was responsible for the rapid installation of motion detector control for the basement and foyer lighting circuits to rectify this issue.
- Ground floor areas were originally designed for retail operation and fitted with full height single glazing for this purpose. These areas were later converted to office tenancies. Heat loss through the glazing led to discomfort complaints from tenants, which were addressed by addition of electric re-heats in the air-conditioning system. These systems were operating in an inconsistent manner, and were re-commissioned to operate correctly, resulting in lower energy use and reduction of tenant complaints.
- Sub-metering data suggested use of the central cooling plant between 10pm and 2am. This was traced back to inappropriate use by tenant cleaners, and was virtually eliminated by the building owner's representative suggesting that an appropriate after-hours fee would be imposed, which lead to a re-training of cleaner operation protocols.

4 OUTCOMES

It is clear that the initial design resulted in a building with good "bones", which achieved a performance of beyond 4 stars NABERS Energy, even when some of the major energy sub-systems were not properly calibrated and operating correctly.

Re-commissioning, by calibrating sensors and ensuring clearly documented control strategies were correctly applied, resulted in the building performance improving to well beyond the 4.5 star level, closer to 4.8 stars NABERS Energy.

Controlling the ancillary energy sub-systems in an effective manner easily improved the performance beyond 5 stars NABERS Energy level. It is not considered difficult to maintain this level of performance, as the building is not "straining" to meet any of the occupant comfort conditions on the floors.

It is noteworthy that the building design does not pander to any ONE attribute for achieving this high level of performance for reduced greenhouse emissions. For example there are no chilled beam systems, ventilated facades or tri-generation systems installed. In contrast, the building achieves this level of measured and verified performance through an integrated approach that:

- Used a concept design strategy that relied on building energy simulation analysis to re-configure systems, reduced over-sizing and integrated the building design across the envelope, facade, electric lighting, air and water sides for HVAC, controls and sub-metering, and developed a clearly documented overall control strategy.
- Used sound design and practical, "keep it simple stupid" (KISS) engineering principles to combine a well understood HVAC system with modern components and control strategies to achieve extraordinary performance.
- Carried out a post-occupancy evaluation of building energy performance after the building had been occupied to 75 per cent and operating for about six months, and then followed through with remedial actions, clearly divided into "defects" and "variations".

5 CONCLUSIONS

It has been clearly demonstrated that it is possible to achieve very high levels of verified energy/greenhouse performance using an "advanced" configuration of the well understood VAV system. In fact, it is our opinion that further improvements in performance are possible by applying modern DOAS (dedicated outside air systems) and control strategies to this system configuration in warm and humid Australian and Asian climates.

The credit for this achievement is a testament to teamwork and collaboration between all parties, and the use of an integrated process of design, delivery, commissioning and post – occupancy follow through. The importance of teamwork cannot be emphasised enough; it requires only one rotten apple in the entire team to bring this collaborative approach to a standstill. Repeatedly emphasising that all are working to a measurable and verifiable performance target may serve to focus the team.

Building energy simulation analysis, when employed by experienced engineers and designers, has the ability to lead to integrated building solutions that achieve measurable levels of high energy/greenhouse performance. BMS and sub-metering systems are invaluable tools in diagnosing, and then correcting, the differences between predicted and measured building performance as demonstrated by the experience at 66 Waterloo Rd.

PROJECT DETAILS

OWNER: **Stockland**

BUILDER: **St Hilliers**

ESD CONSULTANT: **Team Catalyst**

ARCHITECT: **Nettleton Tribe**

MECHANICAL SUB-CONTRACTOR: **Baratech**

BMS SUB-CONTRACTOR: **Control Works**

ELECTRICAL SUB-CONTRACTOR: **Heyday**

PC Thomas

6 ACKNOWLEDGEMENTS

PC Thomas

PC Thomas specialises in integrated building design using simulation tools to assist in the design, delivery and retro-fit of sustainable, energy-efficient buildings. He has a Masters degree in mechanical engineering, followed by 20 years consulting, research and teaching experience in sustainable buildings, building energy simulation, energy auditing, energy efficiency in buildings, and solar energy.

G S Rao

GS Rao has more than 20 years in the HVAC industry. He specialises in providing optimal solutions that maximise HVAC plant efficiency and minimise greenhouse gas emissions using simulation tools and selection software. He has extensive knowledge of products and systems that make up large central plant air conditioning systems for both industrial and commercial applications. ▮

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