FORUM

No. 4 Mort Street reaches for the Stars

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ABSTRACT

This paper describes a heating, ventilation and air conditioning (HVAC) upgrade on the 45-year-old Public Trustee Building located at 4 Mort Street in the Canberra CBD. Significant improvements were made to energy performance, occupant comfort and plant reliability, with the asset value estimated to increase by $1.4M and energy costs decreasing by $120K per annum. The project was carried out within the constraints of a limited budget, space restrictions and the building being occupied during the upgrade.

Important issues behind the success of the project are covered in this paper, including the energy audit, building simulation, Green Building Fund (GBF) grant application, the technology adopted and the commissioning and post-construction monitoring process.

KEY FACTS:

- Building details: NLA 5,400 m^2, 5 storey, Commonwealth multi-tenanted commercial building with one retail tenancy.
- NABERS energy rating (base building) increased from 2 to 4.5 stars, tracking to be 5 stars in 2013.
- Energy cost savings: $120,000 per annum.
- Increase in asset value: Estimated at $1.4M.
- Reduction in greenhouse gas emissions: 786 tonnes per annum (70% reduction), Scope 1,2 and 3
- Capital expenditure: $1.5M.
- Green Building Fund Grant: $0.5M.

This project represents a good example of how teamwork, a systematic approach to design, and attention to detail during the installation and commissioning stages can radically improve the performance of a pre-loved building, in a cost-effective manner. The lessons learnt would be of value to many buildings of similar vintage having typical HVAC systems.

THE PROJECT

1. BACKGROUND

Amid an increasing focus on NABERS ratings and rising energy costs, it is important for property owners to consider the performance of their buildings to increase the attractiveness of their assets to tenants. With the National Green Leasing Policy requirements for the Commonwealth Government and increasingly with private tenants, the minimum NABERS requirement is a 4.5 star benchmark, with some building owners having even higher aspirations. Failing to meet 4.5 stars significantly reduces the leasing appeal of a building to some tenants and eliminates it from consideration by others.

Upgrading an existing building can substantially improve its energy performance, and if managed carefully, the upgrade costs can be more than recovered over time by reduced energy and maintenance costs, increased asset value, as well as maintaining or attracting premium tenants.

Upgrading a 45-year-old commercial office building such as 4 Mort St to achieve a NABERS energy performance rating of 4.5 stars is quite challenging and a systematic approach is essential. The task is even more complicated when the capital budget allowance is limited and the tenants must occupy the building during the refurbishment work. This is a situation currently faced by many property owners and facility managers. Trafalgar (the owners of 4 Mort St) faced such a situation in 2009.

The energy performance of the building was originally approximately NABERS 2 star prior to the upgrade. The HVAC systems, some of which dated back to the original installation in 1965, had reached the end of their economic working life, and were unreliable and expensive to maintain. Energy costs were significantly increasing, and some of the Commonwealth leases were due to expire.

To attract Commonwealth tenants it was necessary for the energy performance of the base building to be enhanced to at least NABERS 4.5 Stars. The building owners were also aware of impending Commercial Building Disclosure (CBD) regulations, which required the NABERS energy rating of the building to be disclosed when advertising for new tenants. Further challenges faced by the building owners were a limited budget for capital expenditure and a requirement to maintain the HVAC systems in operation, enabling the occupants to carry out business as usual during the refurbishment work.

Caption

The building owners appointed GHD as design consultants to assess the options available, and embarked on a pathway to improve the energy performance of the building. This was a collaborative exercise that essentially involved the following key steps:

1. Carrying out a level 2 energy audit of the building, to evaluate the cost effective options available for improving the buildings energy performance, with minimal disruption to the tenants.
2. The successful application for a $500K Green Building Fund grant.
3. Performing a building simulation to further analyse the energy performance and gain confidence in the recommendations presented in the energy audit report.
4. Targeted upgrading of HVAC plant and the base building lighting systems in the common areas. This involved careful design, including paying attention to detail, a high standard of installation and thorough commissioning of the HVAC systems.
5. Fine-tuning of the HVAC systems based on remote monitoring of system operating parameters and energy consumption through the BMS, during the 12-month warranty and maintenance period, until a NABERS energy rating was issued in January 2012.
6. Carrying out best-practice maintenance and operation of the HVAC systems, with continued tracking of performance, to enable the NABERS rating to be maintained and possibly enhanced to 5 stars.

2. THE ENERGY AUDIT

A level 2 energy audit in accordance with AS/NZS 3598:2000 was the first step towards establishing how energy was consumed in the building and to identify cost-effective measures for improving efficiency.

The energy end-use breakdown confirmed that HVAC systems accounted for 90% of the base building electricity consumption, of which 11% could not be allocated to an identified end use, and was therefore assumed to be losses within the HVAC system. This was a clear indicator of energy wastage.

To improve the building's NABERS energy performance essentially involves reducing greenhouse gas emissions from its operation. The energy audit carried out at 4 Mort St pointed out that the following measures, ranked in order of importance for what would have the greatest impact.

1. Changing the energy source for space heating from electricity to high-efficiency gas-fired heating. A new gas supply was provided to the building from the reticulated gas mains off the street. Natural gas (mainly methane) has a much lower greenhouse coefficient (0.24 kg CO_2-e) than electricity (1.07 kg CO_2-e in the ACT) supplied from the network grid.
2. The installation of a new building management system (BMS) to effectively control and monitor the new HVAC systems, using energy-smart control strategies and monitoring capability.
3. The re-instatement of the economy cycle to air-handling systems, to provide free cooling when favorable (cool) ambient conditions prevail. Mechanical failures had disabled the operation of the economy cycle.
4. The installation of motorised shut-off dampers at each floor level to enable selective use of air conditioning after normal business hours by tenancies that actually use the service rather than wastefully air conditioning the entire building. The existing system had no motorised floor isolation dampers, and the entire building was air conditioned when after-hours operation was called for, including every Saturday morning when the retail area (a computer repair shop) was in business.
5. Conversion of the existing constant-air-volume (CAV) type air distribution systems to a variable – air-volume (VAV) type system, which use less energy. This was a challenge due to restricted ceiling space and building occupancy during the refurbishment; therefore non-traditional means had to be adopted to achieve this.
6. Replacing the old reciprocating-type chiller operating on refrigerant R22 with a modern high – efficiency centrifugal machine with magnetic bearings operating on refrigerant R134a (zero ozone-depleting potential) and complete with adiabatic-type cooling pads. As part of Australia's commitment to phase out ozone-depleting refrigerants, R22 imports will be banned from 2016, and owners of such chillers are now facing increased costs for replenishing this refrigerant.
7. Reducing the energy consumed by the tenants' supplementary condenser water loop, through the installation of two-port motorised valves on the condensers of tenants' equipment, and variable frequency drive (VFD) control of the tenants' condenser water pump.
8. Improvement of HVAC system zoning to improve occupant comfort and to reduce wasteful re-heating of air, which was causing conflict between the heating and cooling systems.
9. The installation of separate split-system HVAC units for the retail tenancy, so that the main central HVAC plant did not need to operate inefficiently for a small tenancy on Saturdays, and the installation of electricity sub-metering to exclude the energy consumption of the retail tenants' HVAC from the overall building NABERS rating.

10. Replacing inefficient dichroic-type down-lights with light-emitting diode (LED) type light fittings in conjunction with the installation of simple low-cost automatic lighting control devices to all base building areas, including lift lobbies, toilets, car park, entrance lobby and external lights.
11. Reducing standby energy losses from the two passenger lifts. Due to high capital costs, this aspect was deferred to a later date as part of a lift refurbishment.
12. Control of the car park fan through a variable speed drive (VSD) and carbon monoxide (CO) monitoring.

The design engineers faced practical challenges associated with the building having to be continuously occupied during the refurbishment work and the ceiling void spaces being very restrictive in space. Conventional methods for implementing some of the measures listed here, including the installation of new VAV terminal units and diffusers were not practical because they involved removal of the ceiling and major alterations to ductwork while tenants occupied the floors. An innovative reconfiguration of the existing CAV system had to be designed and carefully installed to achieve the necessary gains in efficiency. These are described later in fact sheets relevant to this project.

3. THE GREEN BUILDING FUND GRANT

An application was made by the property owner for a $500 K grant from the Green Building Fund (GBF). This was administered by AusIndustry and offered grants to provide financial assistance for projects associated with retro-fitting and retro-commissioning existing buildings, including commercial offices, to reduce greenhouse gas emissions by improving energy efficiency.

The consultant's energy audit report was an important part of the grant application, because supporting evidence for the project's potential for making cost-effective reductions to greenhouse gas emissions. The application was successful, and the grant was awarded under Round 3 Stream A.

The award of this grant made a significant impact to the financial viability of this project, further encouraging the building owner to proceed with the services upgrade. The savings in greenhouse gas emissions achieved were 1.6 kg CO_2 per annum for each dollar of grant funding awarded.

4. THE BUILDING SIMULATION

To enable a comparison of the energy performance of the building under different design options for HVAC systems including CAV, VAV and chilled beams, a building simulation was performed. The building geometry, construction details, occupancy loads and equipment ratings were entered into a software modelling package and a building simulation was performed. The model was then used for optimising the selection of key equipment including the chiller plant and the space heating boilers. Chillers and boilers only operate for short periods under maximum duties and results from the simulation provided very useful information on equipment loading under different ambient conditions based on local weather data.

This information enabled the optimum selection of HVAC equipment, taking into account important factors such as part-load efficiency, duty/stand-by capacity requirements and the use of energy-smart control strategies for staging the equipment.

After the equipment selections were made, the model was also used to predict the energy performance of the building after the proposed upgrade work. This provided the design team and the building owners a degree of confidence in regards to the potential success of the upgrade measures for reducing energy consumption. The model also helped to identify potential areas of discomfort to occupants within the different HVAC zones. This information enabled the engineers to re-evaluate and make some changes to the design airflow rates, which were delivered using the existing ductwork systems.

Results from the model were subsequently useful for tracking the building's NABERS performance for the 12-month period following the upgrade work. The heating and cooling thermal energy demands of a building are seasonal in nature, and also depend on factors such as after-hours operation of the HVAC systems. The model predictions enabled monthly targets to be set for electricity and gas consumption, and this information was useful during the post-upgrade monitoring stages. This ensured that the greenhouse gas emissions were within limits to deliver a NABERS energy 4.5 star performance, which was achieved in January 2012 as predicted.

5. THE DESIGN PROCESS

Achieving a 4.5 star NABERS energy rating in a 45-year-old building, while retaining the existing air distribution systems and without any improvements to the building façade required a structured approach, and careful attention to detail. The design team had to consider all the options identified during the energy audit, and engineer the solutions, giving due consideration to staging requirements necessary for the replacement of HVAC equipment, while maintaining business as usual to the occupants during the transition.

The engineers gave focus to all measures, which either delivered energy efficiencies or enabled the investigation and rectification of issues that caused discomfort to occupants, such as temperature fluctuations and draughts. The following are the main features of the upgrade at 4 Mort St that contributed to its success.

- Significantly improving the efficiency of the air-handling systems while retaining the existing ductwork and air diffusers, which were of the four-way type, with poor air diffusion and turn – down capability. The existing system consisted of two air-handling units (AHUs) supplying four risers. The new system has four AHUs, each supplying a riser, thereby improving thermal comfort and eliminating the need for wasteful re-heat. No re-heaters are installed in the building.
- The conversion of the existing CAV system to a semi-VAV-type air-distribution system by installing motorised actuators to the existing manual balancing dampers at the floor branch take – offs. To provide effective control of the semi-VAV system, CO_2 sensors were installed on each floor, and pitot tube-type duct velocity probes were installed to each branch supply-air duct, to provide feedback and a rudimentary form of pressure-independent control.
- Specification of the BMS and energy-smart control functions, which included optimum start and stop, chilled-water reset, economy cycle, night purge, and VAV control including feedback from CO_2 and duct-velocity sensors.

The BMS has web access for remote monitoring, and includes trending capability for features such as energy consumption of chiller and boilers, mechanical switchboard, all electric motors (through VSDs), and thermal energy metering for chilled-water and heating-water systems.

The BMS also had the necessary field items (sensors and actuators) installed to enable back-up (or fall-back) control strategies to be adopted if the designed strategy presented unforeseen challenges during the commissioning and fine-tuning stages.

- Optimised selection of chiller plant, taking into account part-load performance and the forecasted chiller-load profiles obtained from the thermal simulation. The 420 kWr chiller selected is of a magnetic-bearing-centrifugal type, which had twin variable-speed compressors on a common refrigerant circuit (an arrangement that delivers high efficiency), an air-cooled condenser and adiabatic-type cooling pads. The slight loss of energy efficiency when compared to a water-cooled chiller did not have a major impact on energy consumption for this project, and the benefits were the elimination of cooling towers and condenser water pumps, a reduction in water consumption and the elimination of water treatment costs associated with cooling towers.

  It must be noted that a range of factors should be considered before an optimised selection can be made for a chiller type, rating and configuration. These include chiller size, expected load profile, redundancy and maintenance requirements – including service support from the manufacturer, the availability and costs of water and water treatment, the cost of electricity, operating hours, capital and operating costs for condenser water pumps, and the available footprint for equipment. All these factors must be considered on a project-by-project basis before the type of chiller can be finalised and evaluated against NABERS performance and life – cycle costs. Typically, cooling loads smaller than 1MWr tend to favour the selection of air-cooled machines, with the option of installing adiabatic pre-cooling pads for increased efficiency.

- Optimised selection of boiler plant for space heating, which displaced the electric heaters in the old system, taking into account part-load performance and the boiler-load profiles obtained from the thermal simulation. The boilers selected were of the condensing type and of modular construction consisting of three 100 kWh units. The heating coils in the AHUs were sized for heating hot water flow and return temperatures of 65°C/53°C, which enabled the boilers to operate in condensing mode at all times.

  As described previously for chillers, similar factors must be considered before an optimal selection can be made for boiler size, type and configuration. Larger sites would favour a lead (low-load) boiler of the condensing type and the lag boilers (which operate for shorter hours) to be of the conventional type. The convenience of a modular arrangement including the headers, primary pumps and flues, favoured all boilers at 4 Mort St to be of the condensing type.

Another factor to consider is that condensing boilers must have return water at temperatures less than 55°C (the dew point for flue gases) to enable condensation, thereby extracting latent heat from the flue gases and to operate at peak efficiency. Therefore, heat exchangers must be sized larger than with conventional flow and return temperatures of 82°C /71°C, which has cost and space implications. In Australia, space heating boilers in commercial buildings mostly operate under low-load conditions, therefore it is typically not cost-effective to oversize the coils. The boilers can be encouraged to condense under most part-load conditions by enabling (through the BMS) the lead condensing boiler to re-set its flow temperature downwards to maintain condensing conditions except during the small percentage of time during cold weather and early morning warm-up conditions when maximum output is required.

Even after considering the above for 4 Mort St, the heat exchangers were still "oversized" for the lower flow/return temperatures, which enabled condensing conditions to occur at all times because the larger coils resulted in lower air-side pressure drops, which reduced the fan energy consumption. Also the additional costs and space restrictions were not limiting factors.

- The minimisation of wasteful heat transfer from the HVAC systems through the application of extra thermal insulation (beyond the National Construction Code requirements) to new pipework and existing accessible air-distribution ducts. Thermal insulation was applied to all pipeline components such as pumps, valves, flanges and strainers, which traditionally are not insulated. Metal cladding was only used for external pipework, the reasoning being that for internal plant room areas, the money was better spent on thicker insulation rather than on cladding.

6. INSTALLATION

The building owners recognised that the task of transforming 4 Mort St into a high-performance building through carrying out a complete replacement of plant room equipment while maintaining business as usual for the occupants was no easy task. This requires a contractor with exceptional skills for project planning, coordination, communication and technical experience.

The decision was made to pre-select potential local contractors with proven track records, and then to negotiate a price, rather than go out to tender. Since the nature of the upgrade work was mainly HVAC services, it was also considered important for the selected contractor to be a mechanical services firm with project management capability, rather than being a management contractor who was unlikely to add value to the process or to appreciate the complexities of upgrading HVAC equipment while systems were in operation.

This approach proved to be successful. The mechanical contractor was also appointed as the project manager, took ownership of the delivery of the outcomes and paid attention to detail where it mattered, including the electrical/BMS components and the commissioning and tuning process, which typically is the Achilles' heel of HVAC upgrade projects.

7. COMMISSIONING AND FINE-TUNING

Buildings and their HVAC systems need thorough commissioning and fine-tuning in order to deliver optimal performance on energy efficiency and occupant comfort. This process is similar to a ship requiring sea trials before being accepted as fully functional. It is quite unlike the system for manufacturing a mass-produced car, which is ready to run after being driven off the production line.

Unfortunately, commissioning and fine-tuning of buildings is an area that traditionally gets neglected due to the following reasons:

- The installation phase takes extra time, and the commissioning stage gets rushed as a result.
- Main contractors not appreciating the value of commissioning equipment to meet the maximum efficiency or the time it takes.
- Inadequate specification and supervision of the commissioning process by design engineers; contractors offering unrealistically low prices for this section of the works and cutting corners in order to meet their own financial targets.
- A lack of monitoring and fine-tuning during the 12-month defects period.

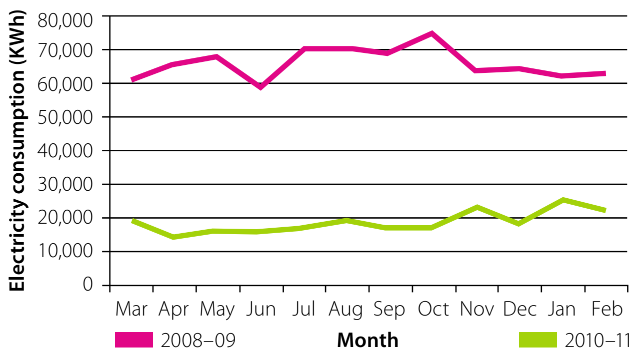
Good commissioning, monitoring and fine-tuning all contributed to the success achieved at 4 Mort St. Attention to detail included the calibration of pitot-type velocity sensors that were installed in less-than-ideal conditions on existing ductwork, due to space restrictions. Monitoring included remote access to the BMS by the contractor and mechanical consultant staff. Strict protocols were in place for change management and there was documentation of any changes to control strategies and operating parameters before any adjustments were made that could have any impact on energy consumption.

The performance of the building continues to be monitored, and with further improvements, the NABERS energy performance for next year is targeted at 5 stars.

8. THE RESULTS

The following graph shows the dramatic reduction in energy consumption of the building.

Electricty Consumption before and after upgrade



- Energy cost reductions of $120K per annum.
- Greenhouse gas reductions of 786 tonnes CO_2-e/y, a reduction of 70% compared with previous years.

- NABERS energy base building rating 4.5 stars achieved in January 2012; tracking for 5 stars in 2013.
- Increase in asset value estimated at $1.4M.
- Total project cost: $1.5M, with a $500,000 Green Building Fund grant.
- Project timeline:
  Energy audit: April 2009
  Thermal simulation: July 2009
  Design documentation: October 2009 to May 2010
  Construction: June 2010 to October 2010
  NABERS Assessment: January 2012.
- Improved occupant comfort due to increased zoning and semi-VAV system.
- Increased plant reliability and better maintainability with the assistance of the remote monitoring capability of the BMS

9. LESSONS LEARNT

The following may be applicable to other projects:

With a structured approach, careful analysis, with optimisation of plant selection and good installation and commissioning, an existing building can potentially be upgraded to achieve 4.5 stars for a cost of $280/m².

With careful planning it is possible to carry out the upgrade while the building is in occupation.

The selection of the project team is crucial. It is important to check credibility and a proven track record of team members. Contact previous clients and visit completed projects to verify.

The GBF grant provided by AusIndustry was crucial for this project to proceed, and its staff were very informative and helpful with the grant application process. It must be noted that if the results achieved from this project (a saving of 786 tonnes CO_2-e per annum) is representative of what was achieved on other projects assisted by the GBF, then the programme would have made a significant contribution to the reduction of greenhouse gas emissions from Australia's commercial building sector.

About the author

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Lasath is a Chartered Professional Engineer who has 23 years' experience working in England, Scotland, New Zealand and Australia. He is the building services group manager for GHD in Canberra. His experience covers building services design, maintenance management, energy management and thermal power plant optimisation.

A keen advocate of energy efficiency in commercial buildings and industrial applications, Lecamwasam has carried out more than 100 energy audits. Lecamwasam is the lead author of the Guide to Best Practice Maintenance & Operation of HVAC Systems for Energy Efficiency, recently published by the Department of Climate Change and Energy Efficiency.

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