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ABSTRACT:
Legislation is demanding that our existing building stock be improved to a minimum of 4.0 Star AGBRS (Aust. Green Building Rating Scheme) energy standards. In the ‘Green Building Fund’ scheme for office buildings and other government incentives, retrofitting our existing building stock makes plain good sense. However, many of the stakeholders (owners, facilities managers, occupants) do not know where to begin to invest, for making these savings.

This paper demonstrates through two case studies, in government related office buildings, how real energy savings were approached and obtained. It illustrates a process whereby preliminary and pretesting results lead to solutions of building ventilation, infiltration and comfort improvement. Furthermore, it discusses how post building performance testing results verified improvement as well as provided inputs to energy simulation, indicating where further invested improvements could be made.

One case study illustrates how the weatherisation of a building prevented a 1.5 million dollar retrofitting spending, costing the client less than one-tenth of the initial retrofitting cost. Another example demonstrates how over-engineering and incorrect ventilation concepts can cost the client up to 70% of their energy bill. Both papers involve real evidence-based pre and post measurement results in existing occupied buildings.

Keywords: evidence-based testing, ventilation systems, building weatherisation

1 Introduction: A need for Retrofitting

Our government endorsed rating tools are often focusing on the newly designed and future buildings. Recently there has been much emphasis on the creation of new “green buildings” with the introduction of higher regulations and minimum energy requirement standards within the commercial sector however, there is currently 98 per cent of Australia’s existing office building stock without sustainability considerations falling far short of a “green building” definition (Taylor 2009).

Yet, there are increasing incentives being made to begin looking at our existing building stock. As climate change effects worsen, mitigation and adaptation approaches in architecture are increasing. A key global challenge of the twenty first century is to discover how to tackle climate change predominantly by reducing greenhouse gas emissions. With buildings estimated to account for approximately half of all energy and greenhouse gas emissions, one potential solution is to ensure that the design, construction and maintenance of the built environment is environmentally sustainable (Miller & Buys, 2008:552).

In Australia, a report released by the Centre for International Economics in 2007 found that 23 per cent of Australia’s greenhouse gas emissions come from buildings in terms of operational emissions (excluding embodied energy); 10 per cent of this was attributed to commercial sector. Figure 1 demonstrates this idea showing the key building types and their greenhouse gas emissions per annum; as one can see office complexes far exceed all other building types in Australia, this equates to an estimated 27% of total sector and 8.5 Mt of CO2 emissions per annum in 1990. (Australian Greenhouse Office, 1999).
Figure 1: Commercial building greenhouse gas emissions (Mt per annum) by key building types 1990  
Source: (EMET Consultants Pty Ltd & Solarch Group, 1999:6)

Figure 2 demonstrates exactly how the operational energy in commercial buildings is being distributed on average with the largest contributors being heating, cooling and ventilation accounting for 70%. The aim of sustainability is to try and reduce greenhouse gas emissions by adapting initiatives within these areas.

Figure 2: Commercial building energy share 1990  
Source: (EMET Consultants Pty Ltd & Solarch Group, 1999:5)

2 A Method Towards Building Retrofitting

This paper, as related to the conference theme of pre-loved building stock, looks at retrofitting existing office buildings. In the scheme of the Green Building Fund and other incentives by government and local councils to improve their buildings, a direction or prescription towards retrofitting is often necessary. Management is generally not trained in the area of building performance, rigorous simulation techniques and guidance towards stages of retrofitting. Furthermore, this guidance is often different for each building, as each building is a ‘prototype’.

In response to the above statements the Six Star Performance Pty., Ltd. group has considered a roadmap towards an effective retrofitting pathway. The following outlines a basic procedural approach, to diagnose building performance problems, in anticipation of the remedial works to improve them. Table I outlines the major heading details only.
Table 1  A Roadmap towards Improved Evidence-based Energy & Environmental Performance in Office Buildings

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
<th>Comment</th>
</tr>
</thead>
</table>
| I     | Preparation for an ABGRS energy audit | • client provides PCA approved plans  
• client provides collected energy bills for a year |
| II    | Scaled floor plans and construction sections, from client | • client provides building material, building envelope (section and elevation) drawings  
• client provides an electrical lighting plan layout.  
• client provides mechanical plant room with layout and information; AHU, chillers, compressors, etc.  
• client provides an HVAC ducting plan layout |
| III   | Perform an advanced walk-through audit | • determine the HVAC mechanical equipment suitability and limitations  
• deliver ‘colour coded’ supply ducting zoning and thermostat locations, AHU identification; capacity and supply air volume.  
• deliver a brief report on the conditions, problems and ramifications of the building services |
| IV    | Perform preliminary actual evidence-based testing: | • provide results according to CIBSE standard of a fan pressurization (building air leakage) test.  
• provide air change rate effectiveness – air quantity delivery test.  
• provide results of thermal comfort at specified areas throughout the building.  
• provide additional measurements of IEQ; (acoustics, façade heat transfer, Indoor Air Quality etc.) upon arrangement with client. |
| V     | Deliver the results of an energy & lighting simulation: | • the above requested drawing are needed to provide this task  
• deliver annual energy consumption and peak load results of the existing building.  
• deliver a proposed ranking of improved strategies and energy savings providing the client with direction on what to implement first. |
| VI    | Devise a plan for the client to remedy the existing problems | • these can be specified and managed by the engaged party. |
| VII   | Post testing and analysis | • post ABGR (one year after implementation of retrofits) audit.  
• air leakage testing (during and after retrofit).  
• environmental IAQ measurements (immediately after retrofit) |

The measurement of actual building performance is something that seldom takes place. At best, a building control system and energy meters may keep a logging of resulting air temperatures and power usage. However, we might query as to what amounts of energy actually are used, when this expenditure occurs, and what the resulting outcome of comfort is.

3 Case Studies

An example of two case studies is provided here. These did not necessarily follow the procedures in Table I. The results of Table I are linked to multiple project testing with the MABLE (Mobile Architecture & Built Environment Laboratory indoor environmental quality testing facility at Deakin
University as well as simulation modeling and experience. The following case studies are intended to support and strengthen the methods provided in Table I.

### 3.1 Deakin University Waterfront Campus: Callista Offices

This project showcases the refurbishment and recycling of a Woolstore building on the Deakin University Waterfront Campus in Geelong Victoria. At the inception of the Deakin Callista Offices, to be located at the top level of the Ford Museum building, the Built Environment Research Group (BERG) was called upon to provide simulation studies regarding daylighting and energy consumption performance (www.yourbuilding).

A simulation using the ENERGY-10 (Balcomb) program with a Melbourne TMY (hourly data) file produced the peak loads for heating and cooling shown in Figure 3 comparing a general base case specified building against a strategic low energy result for the same building. It is clearly noticed that the low energy result is offering a substantial decrease in capital investment of equipment sizing. Unfortunately, the engineering consultant of the project did not accept this proposal at the time.

![Figure 3 The Peak Loading for Base Case and Proposed Low Energy Solution](image)

Finally, the annual energy consumption proposed for this building for the ‘low energy’ case was about 65% less than the base case. The advice on day lighting with regards to glazing selection, size and location as well as control was accepted and proved to be a success, while the information on HVAC sizing, solar shading, and heating, ventilating and air-conditioning concepts were neglected. After several instances of occupant discomfort and complaints, the Callista management decided to engage MABEL to investigate the interior environmental performance of the Deakin Callista offices as well as to perform an occupant survey in February 2005.

The outcomes of the survey performed by KODO Pacific Ltd. Pty. Confirmed the above management complaints (see Figure 4). It is evident that ‘thermal comfort’ is one of the key issues to be resolved in the performance of the building. At around this time the Australian Greenhouse Office were looking for ‘Before and After’ case studies with the MABEL facility. The Bauer Optimising Technologies company who wanted to prove the performance and capabilities of their product, claiming superior HVAC control, also approached MABEL. The implementation of the Bauer Optimising Control System lead to the reduction of the existing AHU (air handling unit) operation as shown in Figure 5. The result was a 40-50% reduction in capital investment of the originally proposed and installed system.

Finally, and astonishingly, the control and comfort of the Callista offices was improved through the Bauer optimising control system, as proposed, with a substantial reduction in existing AHU usage as
well as overall energy conditioning consumption of the mechanical system. In fact, a 70% energy reduction from the original year of operation with that of the new control system was experienced.

Figure 4  The Post Occupant Survey of the Original Callista Offices (source: KODO Pacific, Pty. Ltd.)
3.2 Mornington Peninsula Shire Council: Rosebud Offices

This MABEL project was commissioned by the Building Commission Victoria to investigate the indoor environmental and ventilation performance of the Mornington Peninsula Council Shire – Rosebud offices during the Winter / Spring period of 2007. Most importantly, the before case of measurement refers to the offices as they were ‘before’ sealing the building façade and envelope. Consequently, after refers to the building as it has been ‘sealed’ and tightened by Air Barrier Technologies Pty. Ltd.

The council wanted to improve the existing performance of their office building. In pursuit of this endeavour, they were guided into solutions of retrofitting their building into a ‘power plant’ through introducing co-generation equipment. This costly advice required a $1.5 million estimated investment, which increased to $2.3 million upon an official quotation. After long contemplation, indecision and desperation they decided to ‘test’ the proposal of weatherisation of their buildings. This implied the testing of existing (before) air leakage as well as the Indoor Environmental Quality (IEQ) of the offices. MABEL conducted the IEQ of both ‘before’ and ‘after’ weatherisation (sealing) of the building envelope which was performed by Air Barrier Technologies, Pty. Ltd.

The fan pressurisation method was applied with the equipment pictured in Figure 6. This equipment applied the CIBSE TM-23 standard, as there are yet no Australian Standards. Again, as mentioned previously, testing occurred both before and after the building ‘sealing’ with this equipment. The clients (occupants) were also concerned that levels of CO₂ would not increase and that the IEQ as well as the comfort levels would improve with the weatherisation of the building. It was also ‘promised’ to the client that the retrofit of weatherisation would reduce energy consumption.

The outcomes of weatherisation proved that the offices could be sealed up to 50% and 60% respectively in the two council buildings. As a result of this retrofitting, MABEL testing also indicated an improvement in draughtiness and thermal comfort. Figure C shows the improved comfort between ‘before’ and ‘after’ retrofitting. The results show that the indoor air temperature levels of after hour operation do not drop below the ‘comfort band’ and as a result the pre-conditioning operation of heating the offices seldom took place.
Nevertheless, it was discovered that the 35 year old equipment which has no Building Management Control system was running under a conventional constant volume operation. This implies that there is no variable speed fan operation and that when the system is in running it is 100%. As a result of the weatherisation success there were no equipment failures experienced. Under the ‘before’ condition it was always the case that the system collapsed and failed during extremely hot days. Last year (2008) during a week of 40º C + weather conditions this was not the case, and the system remained in operation, coping with the extreme condition. Therefore, the ‘promised’ energy reduction cannot be met as the system has never failed under the new building conditions (see Figure 8).

<table>
<thead>
<tr>
<th>Building</th>
<th>West Wing Before</th>
<th>Rosebud Civic Centre</th>
<th>East Wing Before</th>
<th>East Wing After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building volume m³</td>
<td>10394</td>
<td>10394</td>
<td>4269</td>
<td>4269</td>
</tr>
<tr>
<td>Test Results</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow @ 50Pa m³/hr</td>
<td>86694.00</td>
<td>46575</td>
<td>31672</td>
<td>19544</td>
</tr>
<tr>
<td>Air Exchanges @ 50Pa</td>
<td>8.30</td>
<td>4.5</td>
<td>7.42</td>
<td>4.56</td>
</tr>
<tr>
<td>Flow @ 4Pa m³/hr</td>
<td>16770</td>
<td>9019</td>
<td>6133</td>
<td>3784</td>
</tr>
<tr>
<td>Air Exchanges @4Pa</td>
<td>1.3</td>
<td>0.9</td>
<td>1.45</td>
<td>0.6</td>
</tr>
<tr>
<td>Improvement</td>
<td>54%</td>
<td></td>
<td>62%</td>
<td></td>
</tr>
</tbody>
</table>

Finally, it is interesting to note that the post energy simulation (after the retrofit) indicates that ‘air sealing the building envelope’ will not provide much benefit in energy savings (Figure 9). It is realised that improved HVAC control as well as ducting air leakage would be advantageous to energy reduction. Furthermore, benefits even extend beyond HVAC equipment and thermal comfort, suggesting that lighting is one of the key advantages of future retrofitting.
4.0 Conclusion

The retrofitting of ‘pre-loved’ buildings can prove to be a very realistic asset for a building owner and its occupants. When considering that over 95% of our building stock is 10 years or older, we require methods and processes towards improving these buildings. Often the building stakeholders, seeking assistance in the matter are mislead by ‘add-ons’ or new products from salesmen. There is no systematic approach to the solution of retrofitting provided.

This paper outlined a suggested roadmap towards retrofitting. The case studies demonstrated this pathway to some degree with ‘before’ and ‘after’ testing and assessment of each project. These methods used in the case studies could benefit from refinement to the process. Nevertheless, they demonstrate the possibilities and huge benefit in retrofitting. In hindsight, both buildings would have benefited greatly from a ‘before’ and ‘after’ AGBRS (Australian Green Building Rating Scheme) evaluation which would have benchmarked their overall improvement on a national ranking level.

References


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[www.yourbuilding.org](http://www.yourbuilding.org), DEWHA, retrieved on 26th August, 2009,