# HVAC Retrofitting for Green Refurbishments in Occupied Buildings

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## About the Author

Mark has been the General Manager of A.G. Coombs Pty. Ltd., one of Australia's leading specialist building services firms, since 2006. In this capacity he has overseen a period of rapid growth in projects across the data centre, health, sustainability and commercial sectors. Mark has been closely involved with the delivery of a number of successful full turnkey infrastructure refurbishment projects which have commenced at early concept advisory, through design development, installation and commissioning and transitioned onto ongoing technical operational support. Many of these have delivered significant green outcomes.

Prior to his role at A.G.Coombs, Mark has held operations and project management positions within the building services and technology industry. Mark holds a Bachelor of Engineering (Hons) and Bachelor of Science from Monash University, a Diploma of Project Management from the University of New England, and an MBA from the Australian Graduate School of Management.

## Abstract

Major retrofits in occupied buildings to achieve energy efficiency outcomes may pose significant issues and challenges. The works are carried out behind the scenes or on a staged basis and it is exceptionally difficult to deliver the works without significant disruptions over an extended project duration.

The essential issue is that most building energy related systems, especially the HVAC are structured and controlled over multiple floors. This combined with usually inadequate system documentation and knowledge can and often does lead to very significant on-site issues. Additionally the major stakeholders: owner, tenants, builder or head contractor, property or facility manager and service providers will all buy into the ultimate objective however they have different and often conflicting agendas and expectations.

A different paradigm is required for these projects: one that is heavy on planning, project management, expert engineering support and most importantly, effective and proactive communication across all project stakeholders. We have done or are engaged in a number of major projects in this genre and share some of our experiences in this paper.

## 1. Introduction

Increasingly existing buildings will have major retrofits for improved green outcomes whilst they are occupied. Our industry hasn't delivered many of these and of those completed, have achieved only mixed results. A.G. Coombs have been involved in a number of such retrofit projects, in a range of different roles, such as mechanical services installer and commissioner, designer, Green Star Independent Commissioning Agent, mechanical services maintenance provider (for base building and tenants), advisor to the owner, and in some instances many of these at the same time!

Through this experience, we have identified a number of recurring issues common to green building retrofits. In the following, these key challenges are explored, and some solutions proposed from our "lessons learned", to improve the handling of these projects for the future.

*The intention is to provide some practical guidance to the industry towards improving its expertise and capability in reducing the carbon footprint of our existing, occupied building stock.*

## 2. Background – Industry Drivers

The property industry is faced with a number of key drivers of HVAC retrofitting for "green" refurbishments within occupied buildings. Note: "green" is used throughout this paper to represent carbon reduction and/or energy efficiency outcomes, often measured by NABERS or Green Star ratings.

There is a growing need to reduce the carbon emissions from our existing building stock. If all office stock aged over 20 years was refurbished to achieve a 38 percent improvement in NABERS office base building energy rating, or up to 4.5 stars, there would be a saving of more than 1.17 million tonnes of greenhouse gas per year, equivalent to taking 266,333 cars off the road [1].

Mandatory disclosure of NABERS Energy performance when selling or leasing a building, from 2010, will make carbon emissions more public and exacerbate this issue.

Increasingly tenants are demanding greater green credentials in their accommodation requirements. For example, the Victorian Government's Green Lease Provisions" [2] policy, as applied to approximately 650,000m$^2$ of their tenanted office space.

To improve the energy performance of a building, upgrades to its HVAC system are generally required. *Significant* performance improvements are often associated with *major* upgrades, which inherently are undertaken in occupied buildings, due to the impracticality and cost inefficiency of relocating tenants.

The combination of the above factors will require the industry's technical and project delivery organisations to respond effectively to the challenges of retrofitting HVAC in occupied buildings for improved Green outcomes.

## 3. Common Issues and Challenges

### 3.1 Limited Scope Definition

The importance of the scope definition and objective-setting phase in occupied green retrofits cannot be understated. In isolation, objectives for such projects are relatively simple and well understood. For example, 4.5 NABERS Energy for base building, a $2M capital works budget, or a 12-month design and construction programme.

However, it is when these objectives are taken in *combination* that they get increasingly more complex, as they sometimes are in direct conflict with each other. For example, maintaining tenant comfort levels, perhaps as part of an existing Service Level Agreement (SLA), whilst reducing energy consumption. Or requiring the completion of installation works to a date which is unachievable given available access to parts of the site, working hours / shutdown factors and noise level constraints.

Poor definition of time, cost and quality objectives and the required scope to their achievement has caused unsuccessful green outcomes on some recent projects.

### 3.2 Competing Stakeholder Objectives and Expectations

A key success factor for a green retrofit project is an awareness of the different benefits it will bring to the various project stakeholders. For the retrofit to achieve its objectives, these different expectations, agendas and interrelationships need to be well understood and managed. Some typical examples are shown in Table 1:

| **Stakeholder** | **Expectation** | **Potential Conflict / Issues** |
|---|---|---|
| Owner | • On time, on-budget delivery<br>• No tenant disruption though construction<br>• Green outcome delivered | • Lack of understanding of technical drivers of green outcomes |
| Tenant | • A better, greener building<br>• No rent increase<br>• No lessening of comfort conditions<br>• No interruption/inconvenience through construction | • Disruption!<br>• Changed comfort conditions |
| Head Contractor / Manager | • Construction site approach<br>• Often working directly for owner (no contractual link to tenants)<br>• On time, on-budget no variations | • FM vs. Builder – control issues<br>• Lack of understanding of technical drivers of green outcomes |
| Property / Facility Manager | • Usually have control of HVAC<br>• No tenant disruption / complaints | • FM vs. Builder – control issues<br>• Lack of understanding of scope (i.e. contract between owner & trades) |

| | | |
|---|---|---|
| Mechanical Service Provider | • Need to maintain contract commitments | • Demarcation – e.g. existing equipment?<br>• Usually responsibility for tenant complaints |
| HVAC Designer | • Green and functional outcomes<br>• On budget | • Need detailed understanding of building – can affect budget and programme |
| HVAC Installation Contractor | • Responsible for most outcomes | • Manage the above stakeholders! |

*Table 1: Project Stakeholder Expectations and Potential Issues / Conflict.*

### 3.3 Difficult Technical Issues

Green retrofitting requires a thorough understanding of the existing and new technologies which, on completion, will deliver the requires objectives and desired project outcome. Failure to do so is a key cause of project objectives not being achieved. Some examples of such technology challenges that we have observed are shown in Table 2:

| **Service / Trade** | **Issue / Challenge** |
|---|---|
| 1. Mechanical | • Underestimating condition and performance of existing equipment.<br>• Existing pipework, discovering corrosion / contamination.<br>• Limited understanding of newer HVAC technologies – e.g. chilled beam and displacement systems.<br>• Lack of "whole of life" thinking resulting in poor "retain & reuse" vs. "replace with new" decisions. |
| 2. Electrical | • Staging of power outages.<br>• Limited understanding of demarcation: e.g. tenant vs. house supplies / boards.<br>• Lack of metering in the base building and tenancy electrical designs. |
| 3. Building Management System (BMS) | • Often an incomplete understanding of the current system performance and extent of original commissioning.<br>• Late commissioning of BAS network infrastructure – should be completed early, as the BMS needs to be progressively handed over after each floor / area.<br>• Lack of training of operators on "interim stages" – e.g. when old and new BMS operating concurrently during upgrade. |
| 4. Fire | • Retaining code compliance during interim stages.<br>• Stair pressurisation requirements can be hard to achieve with existing stairs and hardware not being compatible with the new code requirements. |
| 5. Building Works | • Retention of existing glazing and impact on mechanical heat loads.<br>• New structural penetrations through aging building fabric.<br>• Presence of unknown hazardous materials. |

*Table 2: Common Retrofitting Technical Issues by Trade.*

### 3.4 Lack of Programme Detail

These projects require a dynamic, design and construction works programme for their successful completion. A lack of appreciation of the detail required to carry out such a retrofit can lead to unrealistic stakeholder expectations in relation to works progress and tenant interruption.

There are a number of recurring issues around scheduling these projects that we have found from experience that present (preventable) risks to the project:

- *Incorrectly estimating total durations of works programmes.* Individual task durations are relatively easy to estimate in isolation, but when sequenced and overlaid with tenant SLA / occupancy constraints, become much more complicated. Considerations such as available operating hours, electrical shutdowns, materials handling, access, drain-downs, etc. are not often factored in at the design phase.
- *A limited detailed understanding of the building's current state*. An understanding of plant condition and its impact on the Green outcome is often not completed to sufficient detail, resulting in incorrect assumptions regarding their reuse and subsequent scheduling delays.
- *An incomplete documentation and communication of tenancy access and working hours*.
- *Limited appreciation of which HVAC systems need to be maintained as "operational",* leading to inaccurate staging plans.
- *Inadequate consideration of seasonal timing for thermal plant upgrades.*
- *Poor management of an extended program.* These projects can often go on for many years, particularly based on a floor-by-floor strategy dictated by tenant occupancy.
- *Staged handover and Defects Liability Period (DLP).* With staged delivery over an extended period, DLP maintenance and warranty coverage is an issue as the plant is operational and in use well before the final project Practical Completion (PC).

### 3.5 Unplanned Logistics

From experience, one of the most under-planned areas of HVAC retrofitting for green outcomes is the area of project logistics. In occupied buildings this is often a key driver of tenant disruption, programme staging and overall capital cost.

There is often a limited understanding of which HVAC systems should be maintained "operational" during the staging of a green retrofit. For example, a floor-by-floor staging strategy may be driven by tenant requirements, but how does this related to plant served by vertical riser? Equally, how does the BMS and electrical infrastructure handle this? Will the interim fire mode strategy be operational and compliant? Answers to these questions require a very detailed understanding of the interrelationships between the old and new systems.

Materials handling is often also under-planned and can be costly if omitted. For example, on a recent rooftop chiller replacement project in a 30-storey, occupied office building, the temporary cranage comprised some 15% of the total project capital cost. Alternatives such as the use of an existing goods lift is often impractical or inefficient, and requires close coordination with base building and tenant management. Similarly, horizontal access to plant through occupied tenancy spaces is also often not considered in sufficient detail.

### 3.6 Poor Knowledge Management

The capture, retention and ready access to the knowledge base of a large occupied building has challenged our industry for decades. It can be particularly problematic when retrofitting for a green outcome, as existing design documentation is often (incorrectly) taken as the true and accurate representation of the building's current state, when in practice this is not always the case.

This can lead to a compromised design and installation scope. For example, an AHU plant that has never delivered more than 80%-85% of design capacity. Or an undersized chilled water bypass valve which was significantly undersized, manually "managed" by a building engineer, until he left the building, then the BMS placed in "Auto" and the chilled water plant experienced persistent lack-of-flow shutdowns. Taking design documentation alone as the basis for retrofitting these systems, in the absence of as-installed and commissioning records, proved to be a costly exercise to achieve the intended project outcome. A secondary risk is that if such problems are identified post-retrofit, the underlying cause may be masked by an incorrect focus on the newly installed system elements.

Knowledge management also inherently requires communication and coordination between building operators, users, and the retrofitting D&C team. There is often too little time spent in design briefing and ongoing project stakeholder communication process for such activities.

## 4. Some Solutions, from Experience

### 4.1 End-to-End Project Delivery Approach

We have found that often the standard commercial engagement structures prevalent within the industry are not always the optimum approach for the delivery of green HVAC outcomes into occupied buildings. Delivery models can too easily be broken down into "stages": i.e. briefing, concept design, detailed design, procurement, installation, commissioning, warranty and service/operation. This is also often overlayed by the complication of different providers for each service or trade. This fosters "siloed" thinking around the sub-scope and sub-objectives, rather than the overall outcome.

Alternative delivery models are beyond the scope of this paper, but Table 3 summarises some examples of end-to-end delivery thinking to a few selected project stages:

| **Project Stage (e.g.)** | **"End-to-End" Project Delivery Approach** |
|---|---|
| 1. Design | • Iterative checking of Green (e.g. NABERS, Green Star) model through design development.<br>• Detailed due diligence of condition and performance of existing HVAC system elements to be retained.<br>• Review, including with trade partners, of the proposed system's "buildability" and "commissionability".<br>• Thorough understanding of project programme staging and tenant "touch points".<br>• Consideration in design to AS 1668 compliance through project. |
| 2. Procurement | • A clear trade demarcation matrix, including any client-procured equipment.<br>• Utilisation of outcome-driven performance briefing to equipment and sub-system suppliers - e.g. energy efficiency performance.<br>• Detailed description of the technical connection and interfacing to existing HVAC systems.<br>• Buying criteria should include elements other than capital cost – e.g. whole of life cost (incl. energy and operation costs), lead time and supplier reputation. |
| 3. Installation | • An integrated approach across building services, to mitigate cross-services risk such as fire mode operation and commissioning.<br>• An installation team experienced with working in occupied buildings. This may appear obvious, but often lowest cost providers have more experience in construction site environments.<br>• Consideration during installation to the future serviceability of the retrofitted system – e.g. access, as-installed documentation.<br>• A thorough tenant communications plan.<br>• An "as-constructing" approach to verification of the intended "Green" outcome – e.g. iterative energy performance checks of individual project stages rather than only at project end. |

*Table 3: Examples of the End-to-End Project Delivery Approach.*

In selecting a leader for a HVAC retrofit project, consideration should be given to the project management expertise along with technical aptitude (e.g. a technical consultant is not always the best project manager), and to the proportion of the various scopes of works as constituent elements in the total project. For example, if the HVAC retrofit component represents 80%-90% of the total project scope, capital cost and driver of the “green” outcome, is a builder really the best selection to lead the works?

### 4.2 The Project Plan

A formal Project Plan, documented at the start of the project and updated throughout, is a critical tool to clearly and unambiguously communicate project objectives and define scope. It should set out the requirements of all applicable parties to assure successful delivery and an agreed project management strategy, which will drive the green outcome.

A typical Project Plan contains the following content:

1. *Introduction*
2. *Project Background*
3. *Project Objectives*
4. *Scope Definition (including exclusions, assumptions and related relevant projects)*
5. *Programme*
6. *Project Resourcing*
7. *Budget and Financial Control Mechanisms*
8. *Procurement Plan*
9. *Contractual Issues*
10. *Communications Plan*
11. *Risk Management*
12. *Quality Plan*
13. *OH&S Plan*
14. *Industrial Relations Plan*
15. *Warranty and though-life support*

We have used such a Plan to realign stakeholder expectations and scope demarcation by bringing such issues to the surface early in the project, then communicating through the project delivery team structure, from client through to secondary sub-contractors.

In HVAC retrofit projects within occupied buildings, we have also found a *Tenant Management Plan* to be of real value. This includes documenting processes for communications between tenant and project team, access and shutdown procedures. A simple example is to meet with the local tenant before, during and after retrofit works are conducted within their space.

Such an approach to tenant management provides the project team the unique opportunity of addressing the "Amenity Paradigm" often associated with these projects. One by-product of green retrofits is a change to the very nature of occupant conditioning. For example, increasing temperature set point tolerances from 21°C ± 1°C to a "floating" 19°C to 24°C range, or going from a VAV system to a retrofitted displacement and/or radiant cooling system. Proactive tenant education of these changes has been found to reduce tenant dissatisfaction post-retrofit, substantially leveraging the green outcome benefits to occupants.

### 4.3 Integrated Programme

An integrated programme is one of the most important live documents on any well-run HVAC retrofit project. That is, integrated both *across services* and *between project phases*: design brief through to warranty/DLP and operation. The project programme should include the following key components:

- *Drivers of the critical path*. For example long lead time equipment or design documentation.
- *Strategies to mitigate critical path tasks*, such as early part-design completion milestones and early works procurement.
- *Planned shutdowns*, then used as a communication document between the project team, base building and tenant management teams.
- *Integration of technical constraints.* For example the staging of plant cutovers, floor vs. riser coordination, infrastructure pre-works for BMS, electrical and fire systems.
- *Incorporation of seasonality constraints* – e.g. no chilled water system cutovers during warmer months.
- *A realistic working calendar,* factoring in the above points, plus any area access, noise and dust constraints driving restrictions to working hours.

The programme also provides one of the few visual progress indicators on an occupied HVAC retrofit project, which may essentially be "back-of-house". A visual indicator is another part of a proactive communications plan to tenants and their management.

### 4.4 Logistics Plan

A Logistics Plan should be used to resolve the project's staging and materials handling requirements in detail, early in the project. Retrofit progress is often driven by tenant relocation staging, so the Plan should be a key communications link between the project team and building / tenant management.

In most cases, large, unwieldy HVAC equipment is required to be retrofitted into the occupied premises, so an understanding of materials handling is critical to tenant satisfaction. This includes the identification of temporary cranage (if required), including its structural requirements, the use of loading docks, goods lifts and on-floor access. If managed well, across all trade services and building works, certain economies of scope may exist – e.g. multiple trades utilising a single temporary crane and/or site amenities.

This Plan dictates many of the constraints to programme working hours. It should also be integrated into both the project's Occupational Health and Safety (OH&S) Plan, for manual handling risk management, and the Environmental Management Plan (EMP) for waste reduction / recycling strategies.

### 4.5 Project Team Technical Expertise

While other solutions within this paper look to "systemise" the delivery of HVAC retrofits, experienced resources cannot be underestimated in their delivery. Often similar project scope and scale experience is considered in team selection, without due appreciation as to whether the project was new construction or a retrofit within an occupied building. In assessing credentials of potential team members, both process and outcomes of prior *retrofitting* experience should be rated highly.

Another requirement is to ensure key technical team members possess a proven understanding of multiple services in addition to their chosen speciality, to aid integration. Additionally, "green" credentials (e.g. NABERS and/or Green Star) should be well regarded across many roles, as it assures a knowledge of the intended outcome.

### 4.6 Integrated Commissioning

The integration of commissioning across building services is well-documented and is applicable to HVAC retrofits in occupied buildings. Examples include commissioning for fire mode testing and power fail operation. However, integrated commissioning across project phases is less well understood, yet is equally crucial to delivering project outcomes.

During the design phase, the "commissionability" of the retrofitted HVAC solution should be formally reviewed. This includes everything from interfacing to existing equipment, to locations of valving and field sensors through the chilled water system. An early decision should be made as to what extent those retained HVAC system elements should be recommissioned prior to new works commencing.

This is also the point at which the project staging and any interim operating modes should be resolved in detail – e.g. how do we commission a "hybrid" constant volume / VAV mode when only half of the floors off a common riser are cut over? Is there a part-air/water balance on the floor, then an overall final test once all floors upgraded?

As the BMS provides the single point of visibility into the new and old system, its successful commissioning is a high priority. Further, as the building is occupied, there is only limited opportunity to tune the HVAC systems without tenant disruption, compared to new construction. For retrofitted systems, the BMS commissioning should include off-site “factory” acceptance testing (e.g. live simulation) then on-site commissioning, including documented point-to-point testing *and* software functionality testing.

Finally, BMS “building tuning” through different seasons should be a formal part of the integrated commissioning plan. This is critical as the first phase of transition to operation for the retrofitted building in order to maintain the green outcome beyond the retrofit installation.

### 4.7 Integrated Knowledge Management

A building’s knowledge management should aim to learn from the past to document for the future. An integrated approach should follow a “whole of life” approach to the facility, as shown in Figure 1, covering all of the HVAC retrofit project phases.

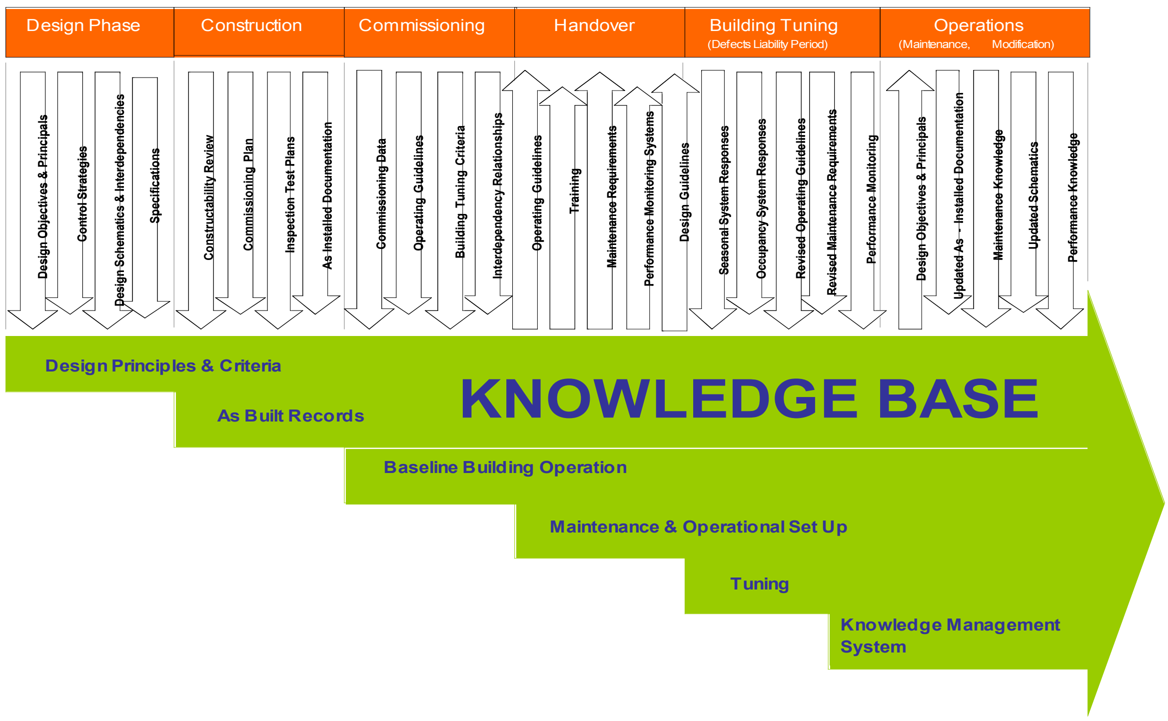


*Figure 1: “Whole of Life” Knowledge Management*

This approach is particularly well suited to green outcome projects to the extended requirements post-retrofit completion. Some of the mechanisms for the above concept is still a work in progress, however in our experience the best-delivered projects have much of the above content in place, in an accessible format to the extended site team. We have found working through a knowledge management plan for a facility is a tremendous stakeholder engagement opportunity.

## 5. Conclusion

Retrofitting HVAC systems into occupied buildings for green outcomes is not easy and not straight forward. As an industry, we have not successfully completed many projects of this nature which are delivering proven, robust green outcomes. However, this will need to change as the drivers of carbon emissions reduction will cause more of these projects to be undertaken in coming years.

Many hidden issues and known challenges exist that have not been well-managed by project delivery teams, particularly those specific to retrofitting into occupied premises. The first step is an awareness of issues likely to affect the outcome of project, which include clarity of scope definition, competing stakeholder objectives and expectations, technical challenges, insufficient programming and logistics planning, and poor knowledge management.

Once identified, an end-to-end delivery approach can be fostered early in the planning stages, which when coupled with a formal project plan, clearly articulates desired outcomes and delivery methodology of the project to its stakeholders. Further, more specific focus can then be applied to communications, logistics and materials handling planning, integrated commissioning and improved knowledge management. This particularly addresses tenant expectation management through proactive communication. Finally, relevant technical and delivery experience of the team responsible for the green outcome is essential.

This approach, from experience, has proven to improve the delivery of HVAC retrofit projects into occupied buildings, and in the process, help reduce the carbon footprint of our occupied building stock.

## 6. References

1 "Property Australia", Article by Mark Beattie, 8th October 2009

2 http://www.vgso.vic.gov.au/resources/publications/PTY/Greenbuildingandgreenleases.aspx