
Designing for Energy Efficient Operation

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To state the obvious, the energy efficiency of a building and its air conditioning system is an ongoing issue. Even the “greenest” buildings must be commissioned correctly and appropriately maintained and operated to achieve their potential. Decisions made during design can help underpin long term energy efficient operation or act as significant barriers to the realisation of the energy efficiency promise.

The requirement to produce energy efficient outcomes necessarily causes designers of air conditioning and ventilating systems to embrace a longer term responsibility for their designs. Designers need to recognise and act on their ability to influence the ongoing energy efficiency, not only through the actual design, its installation and commissioning, but also on into building operation, maintenance and even future modifications.

Design Principles

Often most of the energy waste and the majority of the unfulfilled air-conditioning “promises” in existing commercial buildings can be traced back to the dilution over time of the original design principles and perhaps more significantly the drift of building controls. In both areas the prime issue is complexity and whilst designers have limited scope in what they can do to directly control what happens in buildings after they are built they have considerable influence through the design principles that they apply on the complexity that is built into these systems.

“Is Energy Efficiency the Inverse of Complexity ?”

As soon as a building is completed the change process usually starts. Tenants are keen to further customize the space to ensure it is productive. Any base building design shortcomings begin to surface as the seasons come around and the building services “settle in” and often these are worked around or “band-aided”. Very few buildings enjoy a strongly disciplined change management regime to uphold and build on the original design principles. As such the original design principles can start to dilute very early in the buildings life. The more complex the design principles the harder they are to communicate, understand and maintain. Whilst a more complex system may on paper or in the computer model produce a more energy efficient outcome, can it or will it be maintained in the real world? Will it be so finely balanced that in terms of operation, maintenance and future modifications it will never fulfill the promise?

System complexity is the biggest area where designers can influence the achievement of ongoing energy efficiency. Reduce complexity where possible and this will go a long way to ensuring that air conditioning and ventilation systems will be installed, commissioned and maintained for ongoing energy efficiency.

Building Automation Systems

The technology to be installed into a building should be appropriate to the need. In the first instance is there any point in paying for and installing expensive control and monitoring technology if it isn't going to be used. Will the functionality as specified be actually implemented, be maintained over time, and be of some benefit, or is it simply the latest and greatest from overseas. The more complex the technology the more difficult it will be to set up correctly in the first instance. More complex systems are also harder to maintain. This all leads to endemic problems that cause significant energy wastage and that are very expensive to rectify because of the systems complexity.

It is also important as a designer to recognise that all controls technology will drift and require checking and re-calibration over time. The effect of this is exacerbated by the systems being “fly by wire”, to the extent that there is no direct analogue input in most cases. They are usually not

self-checking or even readily able to be checked. It's not unusual to look at temperatures, airflows and damper or valve settings on the head-end screen and find that they bear little or no resemblance to what's happening in the plant room but "the system is maintaining temperature". Its not unusual to look at a system with multiple outside air sensors all reading different temperatures or systems with a number of air handling systems featuring economy cycles, conditioning effectively the same space with some operating on 100% outside air and some at varying degrees right down to minimum proportions. Building Automation Systems (BAS) are complex, they are totally dependent on quality input and regular checking and calibration is essential.

Recognising this, designers should give some thought as to how these systems can be made to be self checking, even in the simplest sense. They can call for the incorporation of self-checking "reports by exception" to initiate alarms. Parameters and trend logs can be set intelligently to do this. The controls suppliers will not normally do this type of reporting without it being specified. There is the opportunity to establish checking indicators based on commissioning data to warn of drift over time e.g. supply air requirements can be tracked to check drift over time on VAV box and other field controls that can typically manifest themselves as steadily increasing gross supply air requirements.

The dependence on BAS, Direct Digital Control (DDC) and electronic transducers and the desire to reduce capital cost has seen "old fashioned" features like magna-helics (differential pressure gauges) across air filter banks and thermometer pockets and pressure gauges or pressure test cocks on water systems removed from scopes of work. This makes it difficult and expensive to check and recalibrate electronic transducers and consequently it is not done. BAS / DDC calibration checking should be an annual exercise. Features that facilitate system checking and calibration should be incorporated in the design and the requirement to regularly check and calibrate controls clearly specified.

Relatively small deviance's may not cause problems with maintaining space temperature but they can waste a lot of energy over time before they escalate to the point where they do cause temperature problems and are recognised.

The People Factor

Generally a commercial building will operate at part load for the majority of its life and as a rule more energy is wasted in air-conditioning systems during part load operation than during full load operation. Usually design focus is on full load operation and systems and plant such as chillers operate more efficiently when fully loaded. An understanding of how the building operates during part load is important if the design is to be energy efficient and how the building is to be used by its occupants will play an important role in how the design incorporates energy efficiency for part load.

Out of hours operation is one area that is often overlooked by designers, especially for ad hoc usage, and it is becoming more of an issue as working hours become less regulated. A building that will be used for significant periods out of normal business hours will be designed differently that one that is expected to operate mostly during normal hours. Solar and external load profiles will vary from the norm and addressing part load operation will be even more critical.

Out of hours controls for air conditioning is an area that is often an afterthought. If it is not well thought out and made easy to interact with, it will contribute significantly to tenant dissatisfaction and "normal hours" will be extended to quieten complaints. This results in energy wastage in a building with significant ad hoc out of hour's use. There is a lot to be learned by designers from experienced energy auditors in regard to designing systems to best fit with occupant behavior and requirements whilst minimising energy consumption.

Equipment Procurement

Procurement decisions will effect the ability of installers to take responsibility for energy efficient outcomes. There is an increasing trend for clients to purchase capital plant like chillers and boilers or even packaged air handlers in an attempt to minimise capital costs and provide these

items to mechanical contractors to install. Whilst this usually doesn't affect the contractors ability to deliver a system that provides the required performance it can cause problems with regard to warranty and service during warranty, and it inevitably makes it less likely that the contractors will take responsibility for the energy efficiency of the overall system. "Don't hold me accountable for the energy efficiency of the chiller. I'm only running water through it". Designers often have influence over the procurement process and it needs to be thought through and equitable responsibilities clearly defined and communicated if single point accountability for energy efficiency is required.

Commissioning and Tuning

Energy efficient design of air conditioning and ventilating systems is increasingly about integrating the building services into the building physics to ensure adequate levels of performance and energy efficiency. Not only does this require an understanding of the building physics and how they will vary during the year but it also changes the nature of the commissioning task.

Traditionally commissioning has been based on empirical information, preferably from the designer, temperatures, flows, operational regimes for valves, dampers etc. supplemented by the knowledge and experience of the commissioning technicians. The equipment and systems are installed, the piped systems are filled with water, the chillers and boilers are set up, pumps and fans are run and the systems are put through their paces. Design flows and temperatures are hopefully achieved, valves and dampers are driven through their ranges and the systems achieve the stated design capacities. Implicit in this is that if the systems achieve these flows, temperatures etc they will be capable of achieving the design performance throughout the range of circumstances experienced during a year of climatic and internal load variance. It must be remembered that all this is done in a limited period of time at the "end of the job" and often with hand-over deadlines looming. It's done with the ambient climatic conditions at the time and its done with the building unoccupied. It is still rare to see a project with a formal "tuning" requirement written in for the warranty period.

The overall result, whilst not "rocket science" in its individual components and sub systems, when taken as a complete system with the building fabric, and the occupants, is complex and dynamic in its operation.

To commission and set up a system to not only provide the desired internal conditions but also do this in the most energy efficient way possible requires an addition to the traditional set of commissioning information and guidelines, and it should be said a different commissioning paradigm. It requires the designer to have a good understanding of how the systems will consume energy and how these systems should be tuned in the initial commissioning phase and then require tuning over the ensuing period as the building is occupied and the seasons go through their annual cycle. Energy efficiency indicators for application at commissioning need to be derived from the design and energy model by the designer. These should answer the question, "how can we test my built design to ensure it is energy efficient". This will run to a series of empirical tests / indicators for the building systems that will be enhancements to the standard tests, flows, temperatures etc. It should also run to much broader "system" assessments of water and air flows and temperatures and extend into the detail of measuring energy usage / load profiles on installed plant. BAS /DDC systems have a considerable as yet unfulfilled role to play in energy efficient commissioning.

The defects liability or warranty period needs to become something different, it should be a period of tuning and checking to ensure that the systems are performing at their optimum efficiency during all climatic variations for the occupied building. The systems should be tuned during this time to optimise time schedules to best match occupant needs and system performance, and to align the systems operation to the attributes of the built space it serves. As the energy consuming systems and the building are an inter-linked physical system things like warm up times, cool down times, night purge conditions, chiller scheduling, base lighting levels and the like will reflect the physical interaction between the services and the building and this will vary during the year. Commissioning records should be used to track various indicators and as such there is

considerable opportunity for building automation systems to produce controls “silhouettes” describing acceptable parameters for air flow and temperature distribution throughout a building allowing tracking over time and reporting by exception. These are the things that should be detailed at commissioning.

In the last 10 to 15 years, air conditioning designers in response to shrinking fees and changes in project delivery methods have in general focused more on producing documents for pricing and tender. They have moved away from the detailed specification of the commissioning requirements for their designs and reduced their involvement in the physical checking of the installation or its commissioning. Responsibility for commissioning and system outcomes and for setting out detailed maintenance and operational requirements has fallen increasingly to the installers. Whilst it should be noted that the extent to which this has happened appears to vary around Australia this trend must necessarily be reversed if energy efficient designs are to be correctly installed and commissioned for the desired outcome. The designers must be *involved* in their product. This involvement will also improve their understanding of how the installed designs operate, are maintained and how they actually consume energy.

Commissioning Hybrid “Green” Buildings

The dependence on the successful integration of the building services and the buildings characteristics is even greater in “hybrid” or “green” buildings where the aim is to make the most of the buildings passive features to firstly reduce the need for energy consuming systems and then to minimise the size of these systems. A number of buildings of this type built in the last 5 – 10 years have not reached their promised potential because of shortcomings with the building services. In some instances this has been caused by design problems. Particularly in situations where traditional mechanical systems and design approaches have been applied in a new way to a new circumstance and the limitations of these systems and their hoped for integration with the building have not been well understood by the designer or energy modeler. The problems however appear to be more often caused by installation and commissioning problems where the concept of the design and its intended interaction / integration with the building construction has not been adequately conveyed by the design documents or not been fully understood by the installation contractor.

“The buildings great, we don’t have to run the air-conditioning or ventilation systems as much as we thought we would but when we do they don’t work very well and they consume more energy than they should”.

Or with energy recovery systems:

“That systems never worked quite right so we turned it off”

The designer has a pivotal role in the successful commissioning of hybrid systems. Firstly ensuring that the proposed duty to which the systems are to be put is realistic and the desired integration / interaction with the buildings features will work. And importantly in adequately conveying to the installation and commissioning contractors an appropriate understanding of what the systems are to do and how they are to be commissioned to ensure that they operate as envisaged. Unless directed contractors will install and commission systems to the traditional paradigm of ensuring it works but not ensuring it works energy efficiently.

Energy Efficient Maintenance

Traditionally building services maintenance has been all about system reliability and performance, and if you get sophisticated, “asset management”. Reliability and performance is typically driven by tenant complaints and asset management is driven by a relatively recent and increasingly detailed understanding of the role that the cost of building services play in the commercial value of a building and importantly its contingent liabilities come sale time.

Maintenance practices that are driven by the need to maintain energy efficiency are different to those that are usually applied to ensure reliable performance and maintain asset value. Energy efficient maintenance is founded on an understanding of how air conditioning systems consume

energy and where the risks to energy efficiency lie. Economy cycle controls are a classic example. A relatively small deviation in damper settings from the optimum may not result in any noticeable problems with the systems ability to maintain conditions however it may have a very significant affect on energy consumption over the year. With these systems it is often not until the settings are far enough out of calibration as to affect the plants ability to cope with temperature extremes that the problem is noticed and rectified. In the meantime the amount of energy wasted by the economy cycle has far exceeded the energy it was intended to save.

A lot of energy efficient maintenance practices are dependent on information about the design, with settings confirmed at commissioning and the tracking of this information over time against these commissioning benchmarks. This process should be thought through by the designer and set out at design stage with clearly documented procedures for energy efficient maintenance specified for the particular design.

When setting out maintenance requirements it should also be remembered that in most instances maintenance contracts in buildings are awarded to the cheapest price not always the most technically adept. They are also usually awarded for a relatively short period of time, 12 months is still the norm although recent trends are seeing more significant properties moving to 3 or even 5 year terms. In a 12-month contract a maintenance organisation is unlikely to have the budget or the motivation to take the time to invest in understanding how the building services work in detail. This only adds weight to the need for the designer to clearly set out any maintenance requirements that are essential to ensure ongoing energy efficiency.

Operation – The Human in the Loop

Buildings are now more commonly being constructed with hybrid ventilation systems. Using a blend of passive design features and traditional “active” systems these building sometimes put humans in the control loop to a greater extent to what has become the norm previously. This can require the occupants to make adjustments to the buildings features to suit varying climatic conditions, to get the building to perform as intended e.g. opening or closing windows or vents, tuning on ceiling fans etc. In principle this is fine however the role must be clearly conveyed to the occupant, they will need reminding in some way. It should not be forgotten by designers that for the time being at least the dominant paradigm of most commercial and institutional building occupants is that the building will look after itself without any input from them.

Even in more traditional buildings the conveyance of design information, particularly with regard to how the building services are to operate most efficiently needs to be captured and enshrined in the building in some enduring way. This may be via the installation contractors Operating and Maintenance manuals or the Building Automation System. It is noted that experience has shown both these approaches to be fallible over time with O&M Manuals subject to loss and Building Automation Systems subject to change.

Future Modifications

Change is continual in modern facilities, new fit outs, change of use, open plan to enclosed offices and back again and so on. It is important that the essential design information that underpins the energy efficiency of the original system is recorded and available to future designers who are required to modify the systems without compromising the intended efficiency. Design information is not usually passed on from the designer and is not usually recorded in a form that is readily passed on. Both these things need to change if design energy efficiencies are to be maintained over time. There are obviously commercial issues involved and these will need to be addressed. There are also challenges in terms of how the information is to be passed on and made available when required.

Thought could be given to the concept of a designers “handbook” for the building and the air-conditioning systems which addresses energy efficiency issues relating to design, commissioning, maintenance and operation. The information would be kept in trust in some way and appropriate labeling indelibly installed on the systems to indicate to future designers,

installers and maintainers where this information can be obtained. Perhaps an Internet based information repository would be an appropriate solution.

Close

The responsibilities for energy efficient design go well beyond the formal design stage of a project and a successful energy efficient design requires a good appreciation of how the system will consume energy and importantly a sound understanding of how the system will be commissioned, operated and maintained.

Frank Lloyd Wright is quoted as saying, "A doctor can bury his mistakes but an architect can only advise his clients to plant vines". It can be argued that air conditioning designers have by and large remained relatively free of ongoing connection with the outcome of their designs, responsibility for ongoing energy efficiency will change that and design practices will need to change accordingly.

*** About the Author**

Bryon Price is a Mechanical Engineer and a Registered Building Practitioner in Victoria. He is Business Development Manager for the A.G.Coombs Group of companies. A.G Coombs is a leading specialist provider of building services. Bryon is also responsible for A.G.Coombs *Advisory*. This provides technical advice and services to building owners and managers.

Prior to joining A.G.Coombs he was a Director of a large international Consulting Engineer and responsible for a range of national energy and environmental management projects.

Bryon was a founding Director of the Australian Building Energy Council and a Member of the Australian Greenhouse Office Steering Committee for the Scoping Study of Minimum Energy Performance Requirements for Incorporation into the Building Code of Australia. He was a member of the Institution of Engineers National Sustainability Framework Taskforce on Building and Construction and is the Institution of Engineers Australia Representative on Standards Australia Committee EN/3 "Energy Efficiency in Buildings". A member of the Judging Panel for the Master Builders Association National Energy Awards in 1999 and 2000 he was also principal contributor to the 1994 BOMA Energy Guidelines and was similarly involved in the preparation of the 2001 Property Council of Australia Energy Guidelines.

Bryon was a member of the Victorian Governments Sustainable Energy Authority's Industry Advisory Panel and is a co-author of the SEAV Building Energy Brief.