Heating
Ventilation &
Air-Conditioning

High
Efficiency
Systems
Strategy

PEOPLE
PRACTICES
SYSTEMS

Guide to Best Practice Maintenance & Operation of HVAC Systems for Energy Efficiency

January 2012

Council of Australian Governments (COAG)
National Strategy on Energy Efficiency

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Disclaimer

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Project Background – Heating, Ventilation & Air Conditioning – High Efficiency Systems Strategy (HVAC HESS)

The HVAC HESS, a ten-year strategy under NFEE, focuses on energy efficiency improvements in the installation, operation and maintenance of HVAC systems in commercial buildings.

The current three-year work program under the Strategy known as the Cool Efficiency Program commenced in 2009–10 FY.

The Strategy is designed to achieve long term improvements in the energy efficiency of HVAC systems, particularly in commercial building applications. The Strategy is aimed at whole of life improvements in HVAC efficiency, encompassing design, manufacture, installation, operation and maintenance. A large part of the gains targeted are in the maintenance and operation of existing systems in existing buildings, and through the establishment of national standard systems of documentation of the design, installation, operation and maintenance of the equipment.

The Strategy has been designed to address many non technical barriers to efficiency, while identifying and promoting highly efficient technical solutions, systems optimisation processes, and creating the environment in which energy efficiency gains are valued, measurable and sustainable.

With more than 20 separate but complementary measures, the Strategy is aimed at three broad areas of HVAC improvements: Practices; Systems; and People.

This project, funded under the Cool Efficiency Program, is part of the National Strategy on Energy Efficiency, agreed by COAG on 2 July 2009.

Further Information
www.ret.gov.au/documents/mce/energy-eff/nfee/committees/hvac/default.html

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GLOSSARY

AHU	Air Handling Unit
AIRAH	Australian Institute of Refrigeration, Air Conditioning and Heating
AMCA	Air Conditioning and Mechanical Contractors' Association of Australia
ARC	Australian Refrigeration Council
AS	Australian Standard (AS/NZS – Australian New Zealand Standard)
ASHRAE	American Society of Heating, Refrigerating and AirXConditioning Engineers
BACnet	A type of communications protocol (language) used by BMS
BAS	Building Automation System (also refer to BMS)
BCA	Building Code of Australia (since 2011 referred to as the National Construction Code-NCC).
BEMS	Building Energy and Monitoring System (BMCS – Building Monitoring and Control System)
BIM	Building Information Modeling (BIMM – Building Information Modeling and Management)
BMS	Building Management System (also refer to BEMS and BAS)
BOM	Bureau of Meteorology
CAD	Computer Aided Design
CBD	Commercial Building Disclosure
CFC	Chloro Fluoro Carbon (a refrigerant that is banned under the Montreal Protocol)
CIBSE	Chartered Institution of Building Services Engineers
CMMS	Computerised Maintenance Management Systems
COP	Coefficient of Performance (a measure of efficiency of a chiller, also refer to IPLV)
DCCEE	Department of Climate Change and Energy Efficiency
DEWHA	Department of the Environment, Water Heritage and the Arts
EEGO	Energy Efficiency in Government Operations
EER	Energy Efficiency Ratio
EIR	Environmental Impact Rating (a factor that takes into account the environmental impact of HVAC equipment in a building)
FMA	Facilities Management Association of Australia
GBCA	Green Building Council of Australia
GWP	Global Warming Potential
HCFC	Hydro Chloro Fluoro Carbon (a generic type of Refrigerant)
HVAC	Heating, Ventilation and Air Conditioning
HVCA	Heating and Ventilating Contractors' Association (United Kingdom)

ICA	Independent Commissioning Agent
IAQ	Indoor Air Quality
IEQ	Indoor Environment Quality (covers IAQ, thermal comfort, noise and lighting)
IPLV	Integrated Part Load Value (a measure of efficiency of a chiller)
IRR	Internal Rate of Return
Kg CO_2-e	Kilogram carbon dioxide equivalent (used in greenhouse gas coefficient)
KPI	Key Performance Indicator
kWh	Kilowatt Hour, unit of energy equal to 1,000 watt hours, typically used for electricity
LCA	Life Cycle Analysis
LCC	Life Cycle Costs
MJ	Mega Joule, unit of energy equal to a million joules, typically used for gas
ML	Mega Litre, a million litres
MEPS	Minimum Energy Performance Standards
NABERS	National Australian Built Environment Rating System
NCC	National Construction Code (also refer to BCA)
NGERS	National Greenhouse and Energy Reporting System
NLA	Net Lettable Area (measured in accordance with the PCA Method of Measurement)
NPV	Net Present Value
ODP	Ozone Depletion Potential
PCA	Property Council of Australia
PPM	Planned Preventative Maintenance
QA	Quality Assurance
TDC	Total Dissolved Solids
TLP	Tenants Lighting and Power
VAV	Variable Air Volume
VSD	Variable Speed Drive (also known as Variable Frequency Drive)

CONTENTS

LIST OF FIGURES AND TABLES

TABLE INDEX

FIGURE INDEX

1. Introduction to this Guide

1.1 About this Guide

It is hoped that this *Guide to Best Practice Maintenance & Operation of HVAC Systems for Energy Efficiency* will be a change accelerator and encourage those working with maintenance & operation of HVAC Systems to have a sharper focus on improving energy and water efficiency.

The advice in this Guide is relevant to typical Heating Ventilation and Air Conditioning (HVAC) Systems that are installed in commercial office type buildings. It is applicable to existing buildings – both old and new, small to large and different grades from premium grade city CBD to rural. The advice given in this Guide may also be applicable to buildings other than commercial office type buildings. The Guide is also applicable to future buildings that are being designed – it addresses important topics to consider during the design and documentation stages of new projects.

This Guide identifies and recognises the importance of existing Australian and International standards and guidelines for maintenance of HVAC Systems and attempts to avoid the repetition of material already published. Existing publications cover factors for consideration when setting up maintenance contracts including statutory requirements for occupational health and safety, maintenance schedules for reliability, occupant comfort and contract administration. For the maintenance of HVAC Systems in Australia, the availability of the AIRAH application manual *DA19 – HVAC&R Maintenance* is acknowledged. This Guide focuses on energy and water efficiency aspects of maintenance and operation, complementing the advice and maintenance schedules already published in DA19.

WHAT THE GUIDE COVERS:

This guide provides information on the following:

- **Getting best results from existing maintenance contracts to increase energy and water efficiencies from HVAC Systems.** Many of the recommendations in this Guide will give cost effective benefits to Building Owners, Facilities Managers and Maintenance Service Providers operating within existing maintenance contracts
- **Improving the energy and water performance ratings (NABERS energy and water) of existing buildings**
- **Maintaining the performance and efficiencies of buildings that are currently delivering target ratings and require regular monitoring, fine-tuning and re-balancing of the HVAC Systems.** Buildings are becoming increasingly complex, analogous with aeroplanes requiring 'fly by wire' technology in order to keep flying. An example is failure of humidity control in buildings that have chilled beams for air conditioning and the occupants 'getting wet'. This Guide highlights the value of continuous monitoring and ongoing building tuning towards maintaining high performance and efficiency
- **Technical issues** that affect sustainability which are relevant to Maintenance Technicians and Controls and Commissioning Specialists
- **Important topics which are relevant to energy and water efficiencies, for consideration when writing specifications for future HVAC maintenance contracts**
- **Key issues** which Design Engineers and Controls and Commissioning Specialists must consider when designing and working on projects for new buildings
- **Potential energy and water saving opportunities** to consider when maintaining or upgrading HVAC equipment. This Guide promotes teamwork and collaboration between Maintenance Service Providers, Facilities Managers and Building Owners to proactively identify opportunities for saving energy and water
- **Setting up monitoring systems** and key performance indicators (KPIs) to enable benchmarking of the energy and water performance of buildings and to verify the

effectiveness of measures put in place to improve energy and water efficiency

- **Information on the assessment of potential Financial and Environmental benefits** gained through replacement and upgrade options for HVAC equipment.

WHAT THE GUIDE DOES NOT COVER:

This Guide does not provide information on the following:

- Commonwealth, State and Territory mandatory requirements for the maintenance of HVAC Systems including Workplace Health and Safety
- Industrial applications and specialist equipment including steam, compressed air, coal and oil fired boilers, co-generation/tri-generation and data centres. Although much of the background information in this Guide would be applicable, industrial and process applications typically have very exacting requirements for control of parameters such as temperature and humidity, unlike in typical office type environments where such close control of HVAC equipment is not justified
- Design information on HVAC Systems.

1.2 Why consider efficiency in HVAC Systems?

The maintenance & operation of HVAC Systems in commercial buildings has traditionally been carried out with a focus on complying with statutory requirements for health & safety and providing comfort conditions to avoid complaints from Building Occupants. Due to short term commercial pressure, the lowest tender price submission from Maintenance Contractors is often accepted, with little consideration given to long term value for money. Therefore, opportunities for achieving energy and water efficiency gains are neglected and life cycle costs are not given due consideration. The consequences of higher energy and water costs are frequently accepted as being inevitable and passed on to Building Occupants.

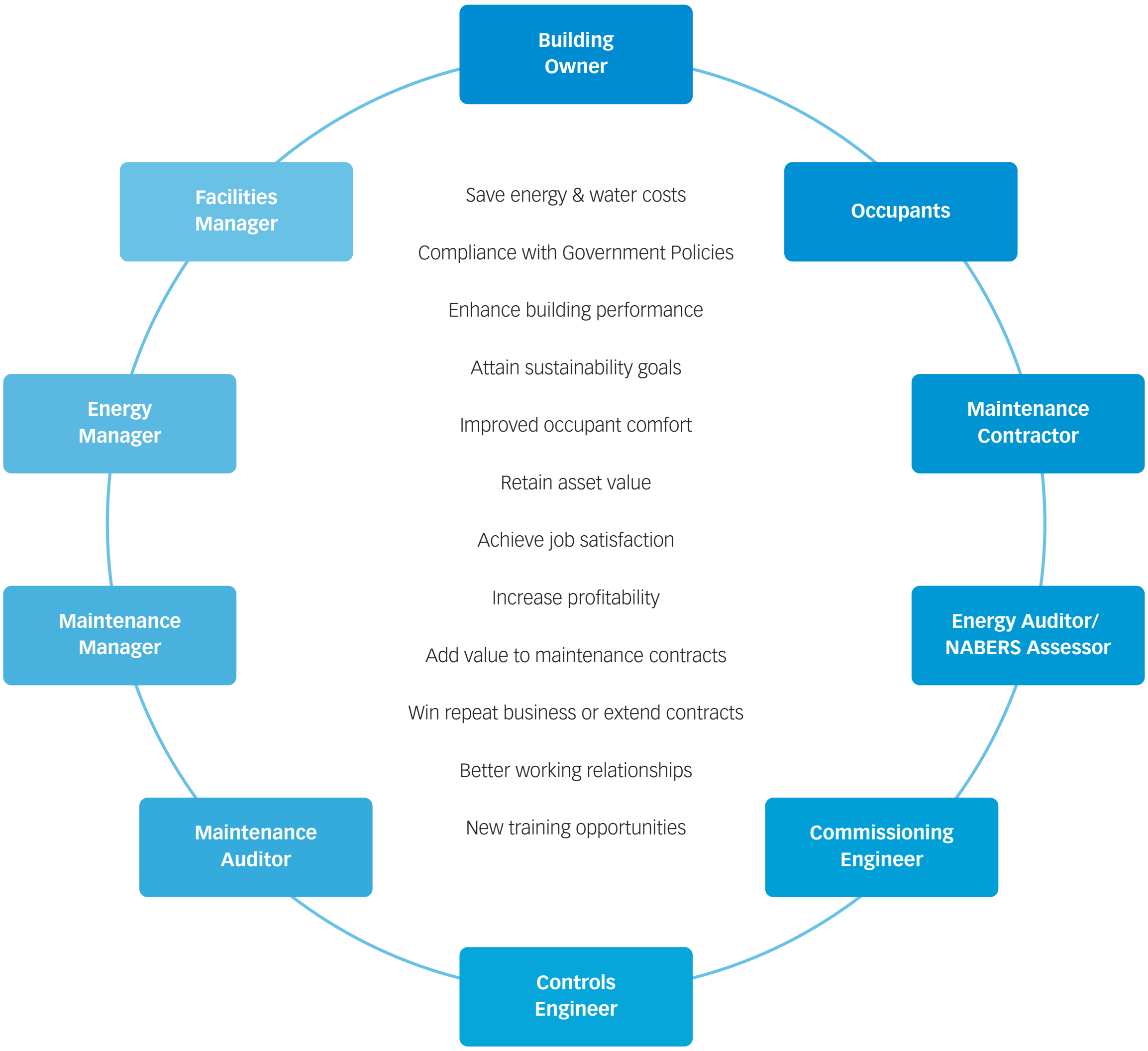
The importance of achieving sustainability in commercial buildings has recently been pushed to the forefront for reasons including the following:

- **Increasing costs for Energy and Water**. Best practice maintenance carried out with a focus on energy and water efficiency can deliver utility cost savings of 10–40% when compared with poor maintenance. High performance maintenance & operation can deliver efficiency gains and cost savings across all types of buildings. Many opportunities for saving energy and water are relatively easy to implement and are cost effective when potential benefits are considered
- The need to reduce the environmental footprint of commercial buildings has become an important part of strategies presented by Federal, State, Territory and Local Governments towards their commitment to **address climate change**, which is now a political issue important to the community
- Under the national policy for energy efficiency Governments have endorsed the national Green Lease policy principal – climatechange.gov.au/government/initiatives/eego.aspx, which gives policy direction to Governments as tenants occupying buildings that have a **demonstrated low impact on the environment**, such as a 4.5 star or higher NABERS energy rating or a 4 star NABERS water rating
- The Commercial Building Disclosure (CBD) regulations mandate the energy performance of buildings to be disclosed and publicly displayed, thereby encouraging Building Owners to **address energy efficiency**
- Commercial tenants are now **demanding to occupy sustainable buildings**. This is driven by an interest to **do the right thing** and corporate commitments to **minimise environmental impact**

- Office buildings in Australia are now designed to comply with building performance rating systems such as Green Star and NABERS. The ability of buildings to **actually perform efficiently** rather than **having the potential to be efficient** is being scrutinised, verified and publicised more than ever before. Proper maintenance & operation of HVAC Systems is essential to deliver good environmental performance
- Apart from financial and environmental benefits, other advantages that high performance buildings deliver include **enhanced occupant comfort, improved reliability** of HVAC Systems and **better retention of asset value**.

For new buildings which have to achieve environmental performance targets, best practice maintenance is the only option that will deliver the high performance objectives demanded by property developers. For existing buildings that perform badly, the initial changes and additional costs associated with implementing best practice maintenance & operation should be viewed as an investment that will deliver a financial return in the long term.

Figure 1.1 Benefits from Best Practice Maintenance & Operation



1.3 Who Would Benefit from This Guide?

For buildings to perform efficiently, all Stakeholders must endeavour to work in collaboration to achieve the sustainability goals which are set by the **Building Owner**. This Guide has information which is applicable to those who are engaged in managing, operating, occupying, and maintaining HVAC Systems in buildings as well as those who carry out design for fit-outs, upgrades and new buildings. Apart from increasing a building's sustainability, additional benefits from using this Guide include cost savings in utility bills, savings in operational costs, improved reliability of systems and better thermal comfort.

This Guide provides **Facilities Managers** with information on key factors that influence the performance and efficiency of HVAC systems and important issues that must be addressed to get the best sustainability outcomes from existing and new maintenance contracts. Advice is given on environmental performance benchmarks and monitoring to target improvements and to verify the results.

Building Occupants have an important role in helping to define a buildings ecological footprint, and are now pushing for performance enhancements in the buildings they occupy. They can make an important contribution to efficient building operation and this Guide addresses issues which are relevant to them.

The HVAC maintenance industry is well placed to make a significant contribution towards enhancing building performance and reducing environmental impacts. **Maintenance Service Providers**, by working in partnership with other Stakeholders, can add value to their work by identifying and implementing cost-effective measures that enhance building performance. This Guide includes practical advice which assists Maintenance Service Providers to proactively identify energy and water saving opportunities during routine maintenance and operational activities. High Performance Buildings could lead to benefits including better recognition, extension of contracts, new business opportunities, and financial incentives for adding value to maintenance contracts and to improve profitability.

Maintenance Technicians will also benefit from better training opportunities, improved morale and job satisfaction associated with working collaboratively towards a defined performance outcome.

Controls and Commissioning Specialists have an important contribution to make towards the delivery of high building performance, and there are sections of this Guide dedicated to them.

It is important for **Design Engineers** to think sustainability and maintainability right from concept design through to documentation, installation, commissioning and sign-off. Smart design and thorough specifications are necessary requirements for Green Design that will have a high impact on a building's environmental footprint. This Guide addresses key issues for Design Engineers to consider.

Energy and Maintenance Auditors monitor the environmental performance of buildings and the effectiveness of maintenance. Their input is important to ensure successful outcomes and the information in this Guide addresses key issues which are relevant to their work.

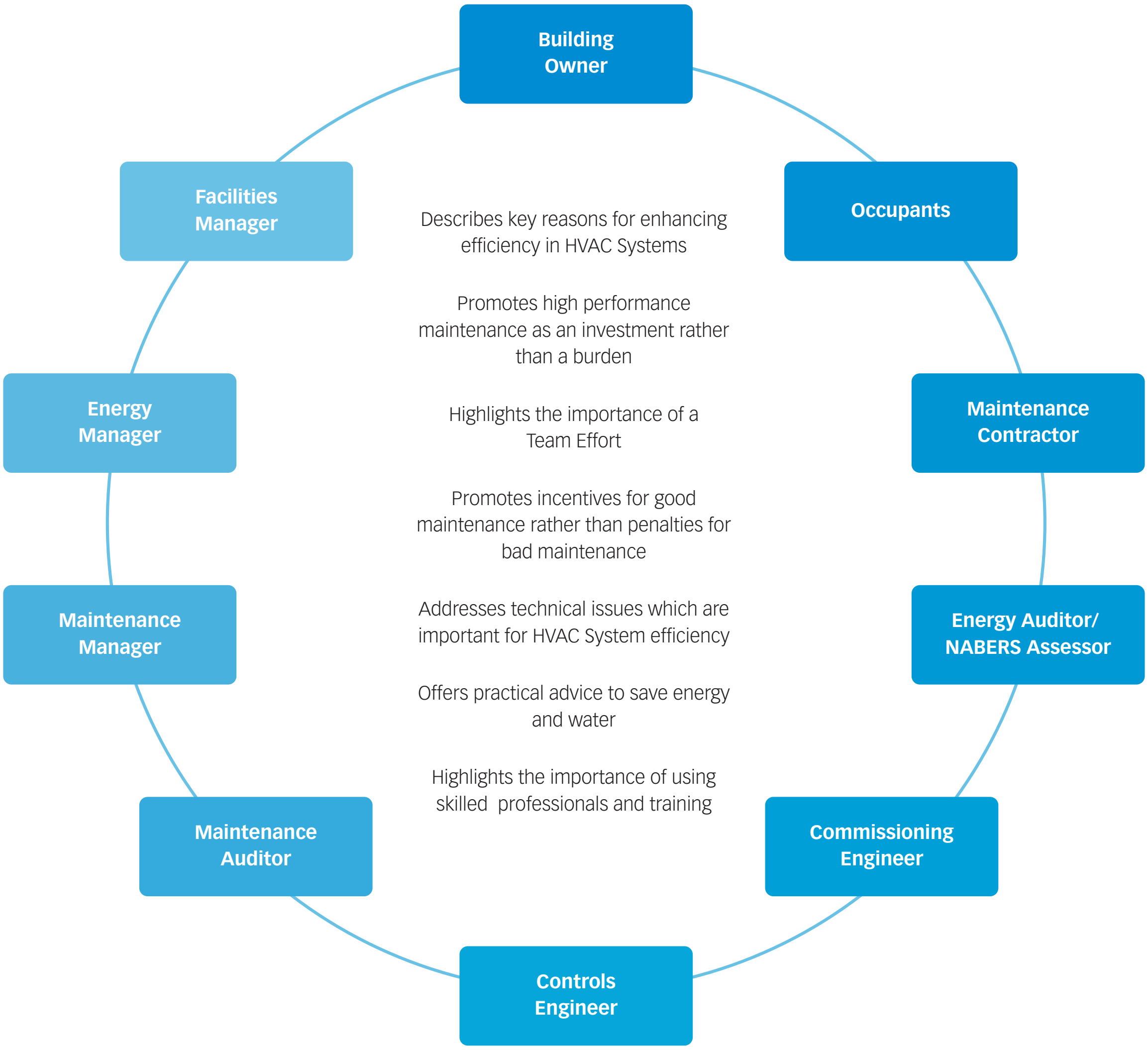
The efficient maintenance & operation of HVAC Systems depends on each Stakeholder being aware of their responsibilities, carrying out their roles diligently in a professional manner and communicating well with one another. For this reason, it is important for all Stakeholders to have a broad understanding of the issues and topics covered in this Guide and other relevant documents referenced in this Guide.

The task of preparing a comprehensive maintenance specification for a facility must not be underestimated. It requires resources from technical, administrative, financial and contractual backgrounds. It is necessary to have a good knowledge of how the building must operate in order to meet the requirements of the Building Owner and the Occupants. Also important is an appreciation of the Facilities Managers strategy for delivering best practice maintenance & operation for the building.

This Guide, as well as other documents referenced, can only provide advice for the compilation of a site specific maintenance specification that will deliver the necessary outcomes. The preparation of a comprehensive maintenance specification may require the services of professional **Maintenance Consultants** and the information in this Guide is relevant to their work.

The Stakeholders who would benefit from using this Guide are outlined in Figure 1.2.

Figure 1.2 Stakeholders who would benefit from this Guide



1.4 How to use this Guide?

Depending on the reader's requirements and experience, reading this Guide from start to finish may not be the most effective way to extract the required information. Figure 1.3 provides a simple map to the various sections of the document, and directs the reader to the areas which are most likely to be relevant to them.

A summary of the contents in this Guide is as follows:

Section 1: Introduction to this Guide

Highlights the important drivers for energy and water efficiency. This section explains what this Guide is about, identifies key Stakeholders and directs the reader to specific sections.

Section 2: HVAC Maintenance Implementation Process

Describes the key steps for implementing high performance maintenance contracts. It covers important factors specific to energy and water efficiencies, which must be given consideration when setting up, carrying out and monitoring maintenance contracts.

Section 3: Building Operation

Discusses some of the key issues that can assist with correct building operation. The contents are written in a bullet point format to enable Facilities Managers, Occupants and Maintenance Contractors to quickly understand the key issues.

Section 4: Documentation

Good documentation is essential for good maintenance. This section describes the key documents that are required for the efficient operation and maintenance of HVAC Systems.

Section 5: Financial & Environmental Evaluation

Outlines some of the tools available to assist Facilities Managers and Maintenance Contractors to achieve better economic and environmental outcomes. If a Maintenance Contractor is able to present a credible business case for the repair or upgrade of HVAC equipment, it is more likely that this will be approved by the Facilities Manager.

Section 6: HVAC Equipment & Efficiency

Explains the main components of HVAC Systems together with their controls and commissioning which have a significant impact on energy and water consumption. This is an important section for technical and service oriented personnel. Facilities Managers will also benefit from an appreciation of how key components of HVAC systems consume energy and water.

Appendix A: Definitions of Key Words

The HVAC maintenance industry has its fair share of technical terms and jargon. The key drivers behind the push to make buildings more sustainable have also introduced a lot of new acronyms and terminology. It is important for all Stakeholders to have familiarity with the meanings of this terminology and understand their relevance to high performance maintenance & operation of buildings, and this Appendix unravels the mysteries behind some of these acronyms and terminology.

Appendices B–H: Checklists

Specific checklists have been included which provide the user with the steps that they need to take and what information may be required in implementing them. The checklists may be also be used as a quick reference to this Guide and are provided in Appendices B to H.

Appendix B: Checklist – Building Owner

Appendix C: Checklist – Facilities Manager

Appendix D: Checklist – Building Occupant/Tenant

Appendix E: Checklist – Maintenance Service Provider

Appendix F: Checklist – Energy and Maintenance Auditor

Appendix G: Checklist – Controls Specialist

Appendix H: Checklist – Design Engineer

Figure 1.3 Document Structure

A	Basic understanding
B	Intermediate
C	Essential reading

Stakeholders	1 Introduction	2 HVAC Maintenance Implementation	3 Building Operation	4 Documentation	5 Financial & Environmental Assessment	6 HVAC Equipment & Efficiency	Appendix A: Definitions of Key Words	Appendices B–H: Check Sheets
Building Owners	C	B	A	A	B	A	C	C
Facilities Managers	C	C	C	C	C	B	C	C
Occupants (Tenants)	C	A	C	B	A	A	C	C
Maintenance Service Providers	C	B	C	C	C	C	C	C
Energy & Maintenance Auditors	C	A	A	A	A	C	C	C
Design Engineers	C	A	B	C	C	C	C	C
Controls & Commissioning Specialists	C	A	A	B	A	C	C	C

1.5 Stakeholder Responsibilities

For buildings to deliver efficiencies and to achieve target performance ratings, it is essential that Stakeholders work in collaboration as a team, making changes necessary to realise the common goal of achieving sustainability. Those engaged in the 'green maintenance' process must have the necessary training, experience and awareness of modern technology and the skills for optimising performance. It is essential to have the right attitude and passion to make a difference.

Figure 1.4 shows a team structure and interdependencies that could exist in a typical building where high performance is to be delivered. Stakeholders need to be aware of their responsibilities and the actions they must take if the benefits from high performance are to be realised and shared.

The responsibilitiesv for each stakeholder are outlined as follows.

1.5.1 BUILDING OWNER

The Building Owner has responsibility for maintaining and operating the Base Building Services. In a Gross Lease the Building Owner also pays for energy costs for the Base Building Services which is recovered from the Tenants as outgoings.

The Building Owner has the most influence for ensuring that buildings operate sustainably and has the potential to motivate and empower all Stakeholders to deliver efficiencies through best practice operation and maintenance. The policies and strategies set by the Building Owner drive the process for setting up the implementation of maintenance contracts and efficiency measures.

It is important for Building Owners to appreciate that any additional costs associated with high efficiency maintenance are investments which deliver returns through reduced long term operating costs, occupant satisfaction and better retention of asset value. For best practice maintenance to be implemented, especially in buildings that have been poorly maintained, there will be initial setting up costs and it is essential that these resources are allocated to those who are tasked with setting up and managing such maintenance contracts.

1.5.2 BUILDING OCCUPANTS (TENANTS)

Tenants pay the utility bills for energy supplied to the tenancy and consumed by tenants lighting and power (TLP). Tenants also have responsibility for the installation, maintenance and operation – including energy costs, associated with supplementary HVAC Systems.

Increasingly, Tenants are demanding that the buildings they occupy are environmentally friendly. This is stimulating other Stakeholders such as Building Owners and Facilities Managers to take action towards achieving energy and water efficiencies. Lease conditions, including Green Leases and Tenancy Fit-Out Guidelines are documents which express the mutual expectations between Building Owners and Tenants with regards to maintenance and performance requirements in buildings.

Tenants can promote the achievement of efficiencies within buildings. They have responsibilities ranging from ensuring that the equipment they operate is efficient, staff behavioural patterns do not affect the efficiency of HVAC Systems and that work carried out during tenancy fit-outs do not affect the performance of base building services.

1.5.3 FACILITIES MANAGER

The Facilities Manager (FM) is usually tasked with the responsibility for Building Maintenance. The FM has to implement the maintenance and environmental policies and strategies set by the Building Owner in accordance with the allocated resources. The FM must take on the role of the Champion who leads the process for implementing changes that deliver energy and water efficiencies. In some larger properties or property portfolios, the FM may be assisted by Maintenance and/or Energy Managers. An important task for an Energy Manager is to set up benchmarks and KPIs that can be used for setting up targets and monitoring the effectiveness of any sustainability measures implemented.

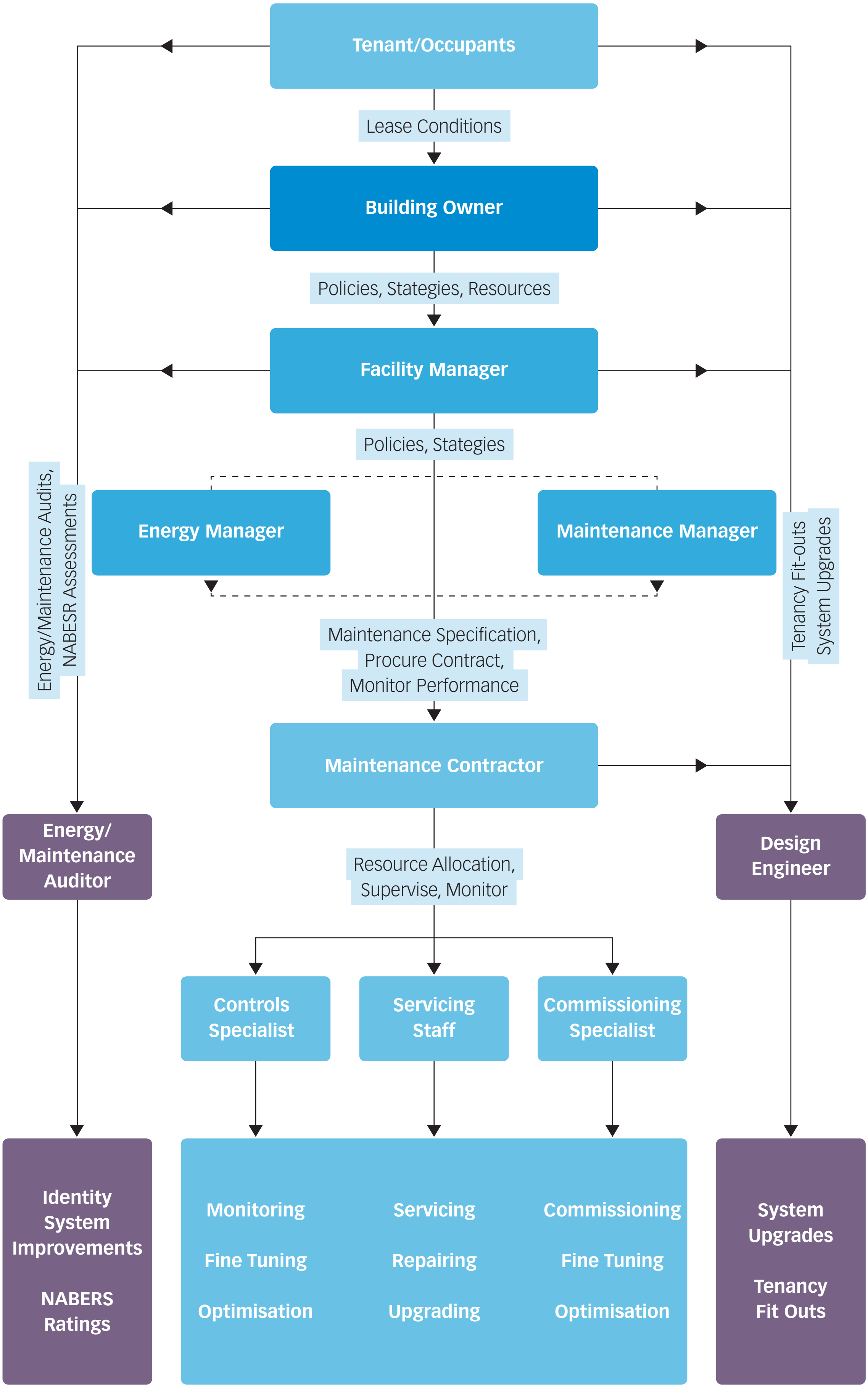
The FM is a key player in the process for delivering high performance buildings. It is important for the FM to develop a maintenance specification that is geared to deliver good outcomes in partnership with Maintenance Service Providers, who should be incentivised for enhancing energy and water efficiency. Forming good relationships and ensuring effective channels of communication including good documentation, is an important aspect to the process.

1.5.4 MAINTENANCE CONTRACTOR

The Maintenance Contractor (or Service Provider) is ideally placed to identify energy and water saving opportunities in HVAC Systems and to implement these measures in partnership with the FM. The Maintenance Contractor should actively promote sustainability thereby adding value to the contract. Better service delivery will improve Client relationships and improve likelihood for the extension of existing contracts and new marketing opportunities.

It is important for Maintenance Contractors to employ skilled resources and to ensure that staff are well trained in the field they operate. Staff should be experienced at identifying opportunities for saving energy and water during their routine day to day activities and must have the right attitude to make a change.

Figure 1.4 Typical Team Structure



The Building Management System (BMS) is an important tool for a Maintenance Contractor to enhance service delivery and it is essential that staff have familiarity and the necessary skills to operate the BMS. Where necessary it may be cost effective to buy-in these skills from a specialist BMS Contractor.

Commissioning and Trouble Shooting skills are also essential to deliver high performance in HVAC Systems and the Maintenance Contractor must ensure that these resources are available.

The Maintenance Contractor's Site Supervisor has a key role to play. Apart from technical competencies, previous experience and good communication skills, it is also essential for the Supervisor to motivate Maintenance Technicians to carry out their work in a professional manner, whilst maintaining a good working relationship with the FM and the Building Occupants.

1.5.5 DESIGN ENGINEER

Design Engineers are engaged by the Building Owner and have responsibility for evaluating HVAC System requirements in accordance with the design brief, performing design calculations and issuing drawings and specifications to be used for installation, commissioning and maintenance during the defects liability period.

Designers have unique opportunities to make an impact on the ecological footprint over the life cycle of new buildings, therefore, they are included as key Stakeholders in this Guide. For HVAC Systems to be operated and maintained in a manner that delivers energy and water savings, the starting point is green design which is essentially based on good design. The Design Engineer also has a major impact on the level of commissioning that is specified and achieved. Consultants working on designs for new buildings and the replacement of existing HVAC equipment need to play an active part towards ensuring that new systems have inherent features that enhance efficiency and are 'maintainable'. Engineers must keep abreast of the rapid technological advances and efficiency gains that are being made and develop solutions that offer best value for money and deliver sustainability.

Increasingly, design briefs stipulate environmental performance requirements and Design Engineers have to focus sharply on HVAC Systems that actually perform efficiently rather than only have the ability to perform efficiently.

It is important for Design Engineers to give attention to the correct specification of commissioning and building tuning requirements, building user guides, operating and maintenance manuals, energy smart controls strategies, monitoring and verification systems together with the necessary sub metering systems – which all have a significant impact on achieving the full environmental potential of a building.

1.5.6 ENERGY & MAINTENANCE AUDITORS

It is important to monitor the efficiency of a building and the performance of the maintenance contract with regards to delivering the necessary outcomes. This monitoring function may be performed by in-house staff or external 'auditors', or a combination of both.

An important aspect of monitoring is to identify reasons for any non-performance and to recommend the necessary corrective action for implementation. To achieve and maintain high performance in a building is analogous to an athlete's fitness program, it needs a disciplined approach.

The achievement of building performance targets such as NABERS energy and water is becoming increasingly important and this requires a continuous 'finger on the pulse' approach, with regards to tracking a buildings performance regularly. Prompt investigations and rectification of faults that cause in-efficiencies in HVAC Systems are necessary to ensure success.

2. HVAC Maintenance Implementation Process

Figure 2.1 shows the important steps for implementing high efficiency maintenance and the key Stakeholders who must participate in the process.

Figure 2.1 Steps to Maintenance Implementation

2.1 General Information		
2.2 Develop Policies & Obtain Corporate Support	Environmental Policy Maintenance Policy Obtain Corporate Support	*Building Owner* *Occupants* *Facilities Manager*
2.3 Develop Strategies & Allocate Resources	Environmental Strategy Maintenance Strategy Allocate Resources	*Facilities Manager* *Maintenance Manager* *Energy Manager* *Maintenance Consultant*
2.4 Prepare Documentation	Asset Register Gather Existing O&M Information Establish Benchmarks & KPIs Produce Maintenance Specification	*Facilities Manager* *Maintenance Manager* *Energy Manager* *Maintenance Consultant* *Maintenance Contractor*
2.5 Management, Monitoring & Training	Maintenence Management Monitoring Training	*Facilities Manager* *Energy & Maintenance Managers* *Maintenance Consultant* *Maintenance Contractor* *Energy & Maintenance Auditors*

2.1 General Information

The subject of setting up and managing maintenance contracts for facilities, including compliance with mandatory requirements for Occupational Health and Safety is comprehensively covered in publications which are well accepted and readily available. It should be noted that mandatory requirements for maintenance vary between the different States and Territories across Australia.

A proper maintenance specification for a building must be compiled as a site specific document. Generic documents with cut and pasted clauses will not deliver good results for energy and water efficiency, or HVAC System performance. It should be noted that the AIRAH DA19 HVAC&R Maintenance Manual gives comprehensive information, including maintenance schedules for typical HVAC Equipment and information regarding the process for procuring and monitoring maintenance contracts. However, it should not be treated as a maintenance specification.

This section of the Guide explains factors important for energy and water efficiencies, which must be considered when setting up maintenance contracts.

For buildings that are covered by existing maintenance contracts which may not necessarily be geared for efficiency, the contents of this section will increase awareness of important issues to focus on. These include setting up an asset register (if none exists or if the available register is incomplete) and setting up monitoring systems. Comparing a building's performance with available benchmarks, identifying potential KPIs and the installation of electricity/gas/water sub metering will all assist to deliver performance improvements. These measures are also essential for gathering the necessary information for setting up future contracts which are focussed on energy and water efficiencies. Under existing maintenance contracts, it may be feasible to cost effectively implement many of the recommendations in this section, and the key message is for Facilities Managers to initiate discussions about saving energy and water, with their Maintenance Service Providers. Opportunities for making savings to energy and water consumption and costs will be lost if Facilities Managers and Maintenance Contractors disregard potential efficiency measures, whilst awaiting for existing contracts to expire.

Important factors that promote energy and water efficiency gains in HVAC maintenance & operation contracts are described in the paragraphs that follow.

Checklists are provided in Appendices B to H to assist the different Stakeholders with the process of setting up and implementing high performance maintenance contracts.

Further Information

1. AIRAH application manual DA19 – HVAC&R Maintenance
2. CIBSE Guide M – Maintenance Engineering and Management: ISBN 978 1 903287 93 4
3. CIBSE Guide to Ownership, Operation and Maintenance of Building Services: ISBN 1 903287 05 7
4. UK HVCA SFG 20: Standard Maintenance Specification for Mechanical Services in Buildings
5. ANSI/ASHRAE/ACCA Standard 180-2008: Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems.

2.2 Develop Policies & Obtain Corporate Support

A corporate policy is important for an organisation's vision on sustainability to be unified and clearly communicated, which is essential for successfully implementing high efficiency maintenance. It is important for Building Owners to develop environmental and maintenance policies for properties and to ensure corporate direction and endorsement is given to strategies for implementation.

Policies (the aims) and strategies (the means for achieving the aims) are sometimes combined into one document.

2.2.1 ENVIRONMENTAL POLICY

An Environmental Policy is a corporate statement of an organisation's aspirations with regards to sustainability aspects that cover Energy, Water, Waste Management and Transport. The Building Owner has responsibility for developing the environmental policy that applies to a building.

An Environmental Policy would typically include the following information:

- An organisation's mission statement with regards to safeguarding the environment
- Clear objectives with regards to achieving energy and water efficiencies. These include environmental targets and goals such as NABERS

and Green Star, the use of renewable energy and goals to be carbon neutral

- Incorporation of any Sustainability aspirations of Building Occupants, including Green Leases
- Timeframe for achieving the target goals
- Mechanism for monitoring and reporting
- Definition of roles and responsibilities for key Stakeholders with clear objectives.

It is important for Maintenance Contractors and other external service providers involved in the maintenance of HVAC Systems to also have Environmental Policies which align with those of the Building Owner. Facilities Managers should request prospective Maintenance Contractors for a copy of their Environmental Policy when requesting tenders for maintenance contracts.

For efficient operation and maintenance of HVAC Systems, it is important for the relevant objectives in the Environmental Policy to be integrated with those in the Maintenance Policy.

Further Information:

AS/NZS ISO 14004: Environmental management systems – General guidelines on principles and supporting techniques.

2.2.2 MAINTENANCE POLICY

A Maintenance Policy is a corporate document which defines the framework and standards to which a building and its services will be maintained. Typically the maintenance policy is developed by the Building Owner in conjunction with the Facilities Manager.

A Maintenance Policy must align with the sustainability objectives in the Environmental Policy. It is unrealistic to aim for high environmental performance without a Maintenance Policy that can deliver this aspiration.

A Maintenance Policy must clearly state the Building Owners objectives for the following:

- Statutory compliance including Local Authority Regulations
- Environmental objectives such as NABERS and Green Star ratings
- Green Lease conditions and objectives
- Energy and water efficiency targets and KPIs for HVAC Systems
- Indoor environment requirements, including indoor environment quality (IEQ)
- Meeting specific requirements of Tenants including response times for attending to faults
- HVAC System reliability and availability targets
- The definition of roles and responsibilities for key Stakeholders. Teamwork, good communication and effective working relationships are essential for Maintenance Contracts to deliver efficiencies
- Details of funding allocations. This is essential to reduce the likelihood of maintenance budgets being targeted as easy pickings during difficult periods, without senior management understanding the consequences
- A commitment to re-invest savings made to make further enhancements. *Success breeds success.*

Maintenance policies must be periodically reviewed and updated where necessary, in order to ensure successful implementation.

2.2.3 OBTAIN CORPORATE SUPPORT

It is essential to obtain corporate endorsement for the environmental and maintenance policies. This will assist with securing the necessary funding, resources and commitment from staff across the organisation for setting up, establishment, operation & maintenance of HVAC systems. Implementing high performance maintenance is dependent on change management and without adequate resources and broad support from senior management, the desired results will not be achieved.

Carrying out effective maintenance & operation of HVAC systems is cost effective over the long term. However, the initial setting-up costs are likely to be higher (than for business as usual) and there is likely to be some initial reluctance and inertia for change. The challenge for those who are tasked with implementing high performance maintenance is to find the initial resources, including the time, to set up such contracts. Where such resources are not readily available, it may be prudent for Facilities Managers to seek the services of a specialist Maintenance Consultant.

2.3 Develop Strategies & Allocate Resources

2.3.1 ENVIRONMENTAL STRATEGY

An Environmental Strategy will address how an establishment intends to achieve the aims outlined in the Environmental Policy. The Environmental Strategy will be developed by senior staff and it will describe key initiatives and means for delivering the sustainability aspirations.

Important issues to consider include:

- Benchmarking and evaluating the existing performance of a building
- Setting realistic performance targets and goals such as NABERS
- Identifying the means to be used for enhancing sustainability. E.g. improving system efficiencies, change management/awareness campaigns/ behavioural change, the use of Green Power, renewable energy and Green Leases
- Resources available, including funding and the availability of skilled professional staff who will implement the Environmental Strategy.

2.3.2 MAINTENANCE STRATEGY

The Facilities Manager must develop an appropriate strategy for the HVAC Systems to be maintained in accordance with the objectives stated in Environmental and Maintenance Policies. The Maintenance Strategy must also consider the resources available in terms of the maintenance budget, in-house staff time and skills available for setting up and administration of the maintenance contract. This is a delicate balancing exercise, which may require the presentation of a business case for additional funding and resources, including the services of a specialist Maintenance Consultant who could assist with the necessary documentation for the maintenance contract.

Maintenance Strategies which are geared to deliver the lowest initial cost, typically focus on carrying out statutory and breakdown maintenance. Scheduled attendance is only allowed for items such as changing air filters and inspecting drive belts, any repairs are carried out at agreed cost rates. With these types of 'poor' contracts, energy efficiency is often sacrificed in order to resolve (quick fix) occupant complaints regarding discomfort. Poor equipment performance such as boiler and chiller inefficiencies and system failures that cause energy and water wastage tend to get ignored or not to be allocated priority status, as long as these issues don't cause occupant dissatisfaction and maintenance call outs.

Common examples of such issues which are not rectified under poor maintenance strategies include:

- Poor equipment scheduling. Due to a lack of planned (scheduled) maintenance, the cooling and/or heating capacity of the HVAC Systems in a building could have diminished. The system takes a long time to achieve comfort conditions to occupied spaces in the mornings, especially after a week end. In order to overcome complaints from Building Occupants, the Maintenance Services Provider bypasses the HVAC time-clock and the plant operates continuously over the weekends and after-hours, with a huge increase in energy consumption which goes unnoticed by the Facilities Manager
- The economy cycle fails and the Maintenance Contractor manually sets the dampers to operate in the minimum outside air position, in order to resolve occupant complaints of being 'too hot' or 'too cold'. As a result, the chillers operate longer hours thereby wasting energy and heating energy is wasted during warm up periods
- Chilled water and/or hot water control valves let through water in the closed position and the cooling system counteracts or 'fights' the heating system. Satisfactory temperature control is maintained but energy is wasted
- VAV terminal boxes and their controls are neglected and go out of calibration. The minimum air supplied exceeds design values to some zones and Building Occupants complain of "freezing" conditions. To resolve these complaints the reheat system (electric heaters or boilers) is kept operating even during summer, thereby wasting a lot of energy due to the chillers counter-acting the heating system and boilers operating in summer. To make matters worse, often the zone temperature control set-points are altered on an ad-hoc basis, creating further in-efficiencies
- Sensors that control VSDs in variable air volume type air handling units either fail or are incorrectly set and the fan speed is not modulated, thereby wasting fan energy consumption. Since the VAV terminals throttle down, there are no occupant complaints and this issue is ignored. Faulty VAV terminals consume excessive re-heat, therefore, energy wastage is higher.

To achieve energy savings from HVAC systems, a strategy which incorporates planned preventative maintenance is essential. Scheduled maintenance, complemented with some condition monitoring using the capabilities of BMS to leverage maximum advantage, is the best option. Tracking system performance, fine tuning and ongoing commissioning are also important.

Active monitoring of HVAC systems through the BMS is important and prioritisation of fixing any defects that lead to energy and water wastage is important. If such issues are not diagnosed and remedied promptly, energy and water wastage will result and the effect on the building's performance including NABERS, could be significant.

To get the best outcome from a maintenance contract, Maintenance Service Providers should be empowered and incentivised to go beyond simply remedying faults that occur and encouraged to look beyond existing constraints and boundaries. As part of their day to day activities, Maintenance Service Providers are ideally placed to actively identify opportunities that reduce energy and water wastage and deliver cost effective savings. Contractors must collaborate with the Facilities Manager to deliver the key performance objectives defined in environmental and maintenance policies.

The Maintenance Strategy will need to be customised to the building. Factors including the age and condition of the equipment installed, the sophistication of the BMS and monitoring systems and the capabilities of local Maintenance Service Providers must also be considered.

In newer buildings, the priority would be to maintain peak performance of the equipment. In older buildings, consideration will need to be given for the replacement and/or upgrade of plant as part of the maintenance contract. Continuing to operate obsolete, unreliable and inefficient equipment is likely to be more expensive than to replace.

Buildings that have sophisticated BMS will be more suitable for condition based maintenance whereas older buildings are likely to be biased towards adherence to maintenance schedules. Other factors to consider include the level of service required to meet specific Tenant requirements and the achievement of building performance ratings.

2.3.3 ALLOCATE RESOURCES

For new buildings which have environmental targets to deliver, there is no option but to implement high performance maintenance. Attempting to cut corners in maintenance to try and save money runs the risk of losing a buildings environmental performance rating which will have serious consequences when Green Lease conditions apply and NABERS commitment agreements have been made. For the same reasons, high performance maintenance is essential when existing (older) buildings are maintained to high standards, delivering high environmental performance.

When high performance maintenance is to be applied to existing buildings which are performing poorly due to inadequate maintenance, the initial costs associated with setting up and implementation will be higher. Staff resources will have to be allocated to prepare the necessary documentation, including compiling an asset register and a good maintenance specification. If the existing equipment has been run down over a number of years, there will be a backlog of maintenance issues that will need catching up, including the replacement of some plant.

It is essential for the Building Owner and Facilities Manager to understand the initial challenges that will have to be overcome.

In order to set up and successfully implement high performance maintenance to a poor performing and neglected building, the Building Owner must ensure that sufficient resources are made available in terms of professional staff and funding. The Facilities Manager could lead the process and be the 'champion' for implementation but will need to be adequately supported.

The input from specialist Maintenance Consultants may be required to comprehensively assess the likely costs and benefits through high performance maintenance and to prepare the necessary documentation.

2.4 Prepare Documentation

It is important to provide the relevant information about a building and its HVAC Systems to Contractors during the tendering stage. This will enable accurate estimates to be made for resources including costs and skill levels of staff. If a Maintenance Contractor fails to understand the requirements of a building and underestimates the necessary resources, the contract will be destined to fail in delivering a successful outcome.

2.4.1 ASSET REGISTER

Before setting up and managing a maintenance contract it is essential for a comprehensive Asset Register to be compiled, listing all major items of HVAC equipment in a format that is useful to a Facilities Manager and Maintenance Service Provider.

An Asset Register can be compiled using information available on Operating & Maintenance manuals. A site survey will be required if the information on the manuals is in-accurate, as typical for older buildings, where the Asset Register has not been updated. It may be necessary to obtain professional assistance to carry out a survey of the building and compile the Asset Register, especially if factors such as equipment condition are to be captured.

The information in the Asset Register provides information on equipment that must be maintained under a contract, which enables reasonable estimates for resources and costs to be allocated by Maintenance Service Providers. If a Contractor is not made aware of the equipment that exists in a building during tender stage, it is unreasonable to expect a reasonable tender price and for a Maintenance Service Provider to deliver a satisfactory level of service.

An Asset Register must include details of equipment location, manufacturer, model number, serial numbers, equipment duty, date of manufacture and cost to replace. Once the asset register is established and a maintenance contract is set up, the responsibility for updating the Asset Register can be passed on to the contractor, with regular QA checks performed (either by the Facilities Manager or the Maintenance Auditor) to ensure compliance.

It is important for HVAC equipment in an Asset Register to be given an Environmental Impact Rating (EIR) that quantifies their potential impact on energy and water consumption. Refer to Section 4.6 and 4.7.

2.4.2 EXISTING OPERATING & MAINTENANCE INFORMATION

Refer to Section 4.2 for a description of typical O&M manuals and their contents.

The information on existing O&M manuals will provide a good start. For newer buildings, these manuals should be accurate and easily available. This may not be the case for older buildings and if manuals are not available, it may be worthwhile contacting the original design consultants or the installer, who may have archived copies available. Contacting equipment suppliers and the controls specialist who carried out the original installation may also be options.

Information available from equipment and site log books would also be useful to Maintenance Contractors tendering to provide a service contract.

Some of the data stored in a CMMS including fault logs, call-out histories and readings from hours-run counters would also give tenderers a better idea of the magnitude of the task.

2.4.3 ESTABLISH BENCHMARKS & KPIS

> *"If you can't measure it, you can't manage it"*
> Peter Drucker – Management Guru

For maintenance contracts to deliver energy and water savings, the establishment of suitable benchmarks and KPIs is important for the following reasons:

- Using relevant rating tools such as NABERS energy and water is a credible method of comparing the performance of a building with others. This also gives the means to estimate potential energy and water savings that can be gained with an assessment of the projected cost savings. For example, if a building has a NABERS energy rating of 2.5 stars (which represents average performance) an assessment can be carried out to estimate what the potential energy savings would be if measures are implemented to improve the rating to 4.5 or 5 stars (which represents best practice or excellence). Facilities Managers and Maintenance Service Providers can easily perform this estimate themselves, by using the NABERS online calculator
- The establishment of benchmarks and KPIs is essential for stating the existing performance of a building and for setting contractual targets for Maintenance Contractors to either maintain this performance during the contract or for offering them incentives to improve the rating. If credible KPIs are established and agreed as part of contractual requirements, this would form a sound basis for verifying whether Maintenance Service Providers are actually delivering energy and water savings
- For any financial incentives offered for maintaining or enhancing energy efficiency to be workable, it will be necessary to contractually agree the KPIs against which the Maintenance Contractor's performance can be tracked
- Recent drivers for the installation of energy sub metering, including Green Star, NABERS and EEGO requirements, together with the availability of sophisticated and user friendly BMS, makes it easier for important KPIs and system parameters to be continuously monitored and trended and for the system to automatically report abnormal trends (exception reporting). Such features are useful to Facilities Managers and Maintenance Contractors to proactively identify HVAC Systems that perform in-efficiently and to carry out trouble shooting.

Benchmarks and KPIs for buildings can be set up at different levels, as described below:

At Building Level

These could be NABERS energy or NABERS water ratings for the base building and whole building respectively. The difficulty with this approach is that these ratings include the energy and water consumption of systems other than HVAC. Therefore, unless a holistic approach is applied to a contract (such as an energy performance contract methodology) and the Maintenance Contractor is safeguarded for factors outside their control, this level of KPI is of little use contractually, for HVAC Systems.

At System Level

KPIs could be set at system level, such as the electricity consumption at the mechanical services switch board (MSSB) or, gas and water consumption to mechanical plant including cooling towers. Monitoring the trends of these parameters will give Facilities Managers, Contractors and other Stakeholders a good indication of the general state of efficiency of systems. However, these KPIs would be difficult to enforce contractually unless they are normalised for factors including system operating hours and extraneous influences such as heating degree days and cooling degree days (dry bulb and/or wet bulb). It is beyond the scope of this Guide to define KPIs that would be contractually accepted across a range of different buildings, however, with some specialist assistance, the Facilities Manager should be able to develop some good site specific KPIs.

At Equipment Level

The efficiency of major energy consuming equipment such as chillers and boilers depend very much on proper maintenance & operation. Through the installation of thermal energy metering, electricity and gas sub metering, KPIs such as chiller coefficient of performance (or preferably the chilled water system COP) or boiler system efficiency can be monitored, this could be made a contractual requirement and the information would also be valuable for diagnostic purposes. Similarly a KPI could be developed for cooling towers, based on proven past performance or best practice estimates, which could be used for monitoring purposes.

Other Means

There are numerous means readily available for Facilities Managers, Building Occupants, Contractors and other Stakeholders to 'feel the pulse' with regards to HVAC System efficiency, two examples are given below.

Analysing the ½ hour time of use electricity data (also known as 'interval data') which is typically available free of charge from utility suppliers gives an easy method to check whether HVAC plant is wastefully operating out of hours (including weekends and public holidays) and for checking maximum demand kVA and power factor. Because such issues have a significant effect on energy consumption and costs, it would be feasible to include the regular reporting of these as contractual KPIs.

Setting up trends on equipment such as VSDs can provide a lot of information which could be used to verify the performance of HVAC Systems. Cooling and heating calls can be monitored and verified whether they are legitimate or spurious.

Note: Credible information regarding end use breakdowns for energy consumption is lacking in Australia at present and this is hampering the availability of 'rule of thumb type' benchmarks. This situation will improve as more buildings are installed with sub-metering and information is available.

2.4.4 PRODUCE MAINTENANCE SPECIFICATION

It is essential for the Maintenance Specification to be tailored for the requirements of a building. Customised maintenance schedules and task specifications based on guides such as AIRAH DA19 must be developed for the building, together with the necessary performance or condition based requirements specific to a building's HVAC Systems.

The task of preparing a comprehensive maintenance specification for a building that has been poorly maintained must not be underestimated. It will require resources from technical, administrative, financial and contractual backgrounds. It will be necessary to have a good knowledge of how the building must operate in order to meet the requirements of the Building Owner and the Occupants. Also important will be an appreciation of the Facilities Managers strategy for delivering best practice maintenance & operation for the building, including maintenance budgets. It is unlikely that adequate funding will initially be available to replace all obsolete equipment. Therefore, the replacement of plant will have to be prioritised and planned in line with the expected availability of funding and the anticipated useful working life of the equipment.

Unless the required skills for compiling the maintenance specification are available in-house, this task is best performed by a consultant with knowledge of HVAC maintenance.

Decide on Contract Type

The Facilities Manager must procure a maintenance contract that is likely to deliver the key requirements of the building maintenance strategy, with consideration given to the available budget and resources to manage the contract.

There are a number of types of maintenance contracts used within the Building Services industry including the following:

Service Level Agreement:

These define the required outcomes for the building including parameters such as the hours of operation, plant availability, design parameters such as space temperature requirements and energy and water consumption targets. A Service Level Agreement would not typically state the specific task details for building services maintenance, it would refer more to high level requirements.

Planned Preventative Maintenance:

A frequency based maintenance contract whereby the Maintenance Service Provider inspects and carries out servicing to equipment in accordance with schedules issued with the contract. The schedules are typically obtained from documents such as AIRAH DA19 and are based on accepted industry best practice to deliver equipment performance whilst minimising down time. Schedules may also include equipment manufacturer's special requirements for certain equipment.

Fully Comprehensive Contract:

A maintenance contract that covers all maintenance including scheduled, repair and breakdown maintenance.

Specialist Services:

A maintenance contract for recognised specialist maintenance. In HVAC an example is building control system maintenance. This can be a sub contract through a main contractor maintenance contract or contracted direct by the Facilities Manager or Building Owner.

Define Scope of Works

The contract documents must clearly define the scope of works required to cover issues that affect energy and water efficiency, and would typically include the following:

- A clear statement on sustainability objectives covering energy and water saving goals, existing and target building performance ratings
- Clearly stated objectives for either maintaining the existing performance ratings, including energy and water consumption KPIs for HVAC Systems or targets for improvement with any incentives offered
- Scheduled maintenance requirements, typically in accordance with established schedules such as in AIRAH DA19, noting that the Facilities Manager and/or the Tenderer may wish to modify (improve) these schedules in order to deliver the necessary outcomes. Should this be the case, the Facilities Manager and the Contractor must state these variations in the tender documents
- A system of priority call outs for issues that affect energy and water wastage. Traditionally such call outs are reserved for issues that potentially affect Health and Safety and loss of amenity. However, these must be extended to cover energy and water wastage as well
- The maintaining of reporting systems, logbooks and records
- Updating the asset register
- Regular reporting of energy and water consumption together with KPIs for HVAC system performance
- The format for presentation of energy saving opportunities, including business cases, for consideration by Facilities Manager.

Specify Contractors Experience & QA Systems

The capability and track record of a Maintenance Contractor is important to deliver the desired outcomes through an effective partnership with the Facilities Manager and other Stakeholders. These expectations must be clearly stated in tender and contract documents, including requirements for QA, Environmental and Health & Safety Policies of the contractor.

It is essential for contract documents to describe the minimum trade qualifications, and experience of key personnel who would be working on the contract. Unless these requirements are clearly stated in contract documents, Contractors may be tempted to reduce costs by employing unskilled staff who may be incapable of delivering the necessary results. Training is an important topic for the HVAC industry and is addressed in Section 2.5.5.

The skill level and experience of the Maintenance Supervisor is essential, and key attributes include the following:

- Trade qualifications and experience with the installation, operation & maintenance of HVAC systems including chillers, boilers, air distribution systems and electrical work. Familiarity with AIRAH best practice guides including DA19 is essential
- A sound knowledge of BMS systems, this may be achieved by the contractor including the services of a BMS Specialist
- A good appreciation of commissioning and balancing of HVAC and controls systems,

including familiarity with CIBSE and ASHRAE commissioning guides

- A working knowledge with sustainability issues and building rating systems including NABERS and Green Star, preferably having attended the courses run by these organisations
- Experience with working within environmental management and quality assurance (QA) systems
- Good communication skills including verbal and written skills. The ability to build relationships with Stakeholders including the Facilities Manager and Building Occupants
- Commercial awareness including the ability to present a written business case for implementing energy and water conservation measures.

It is important for the contractor's staff working on maintenance contracts geared for high efficiency to have the necessary training.

Specify Incentives for Efficient Maintenance

Rather than contracts only being punitive for non-performance, they should also encourage good performance through incentives to Contractors who either maintain a building's high performance or enhance it. Incentives need to be contractually stipulated and tied to KPIs and agreed service levels. Incentives can take a range of forms including an extension of the present contract, a favourable weighting factor for the next tender, financial incentives to enhance building performance ratings or a shared percentage on utility cost reductions. Any incentive that promotes Maintenance Contractors to act in partnership with Facilities Managers will also improve communications and develop a better working relationship, and this will result in mutual benefits which go beyond financial gains.

2.5 Maintenance Management, Monitoring & Training

2.5.1 MAINTENANCE MANAGEMENT

Upon the award of the HVAC operation and maintenance contract, it is essential to monitor and verify that the Contractor is delivering the key objectives necessary for a successful outcome. Maintenance management may be carried out by the Facilities Manager or the Maintenance Contractor, the latter is more common, with regular monitoring carried out by the Facilities Manager, sometimes with external auditing carried out by Independent Consultants (Maintenance Auditors), either at the request of the Building Owner or Occupants.

Subcontracted maintenance will also require monitoring. Controls maintenance in particular has a great bearing on HVAC energy efficient operation and maintenance and will require monitoring as part of the planned preventative maintenance program.

Regular communication and feedback is necessary to ensure that Contractors are continuously monitoring the important performance indicators and are proactively identifying opportunities to save energy and water. Any major equipment that needs replacement or upgrading must be considered as opportunities to deliver enhanced energy and water savings through careful selection for optimised performance rather than a simple like for like replacement.

Records of maintenance carried out must be updated in maintenance logbooks.

Planned preventative maintenance must be carried out on HVAC systems as per the maintenance schedules in accordance with the task detail and standards required. This can be managed through the use of a paper based system in conjunction with commonly available PC based software or by using a sophisticated computerised maintenance management system (CMMS).

Effective management of HVAC operation and maintenance can be improved through the use of a CMMS which would be cost effective for buildings which are complex and have many assets and associated work tasks that cover a variety of different trades and contractors with interdependent activities that need coordination. There are a number of systems available and they typically consist of an asset register, work task details, a maintenance scheduler and status report. A CMMS system can assist with the delivery of energy and water efficiencies. Task details would be clearly detailed on work instructions, the instructions issued in a timely manner with ongoing progress records maintained. Using a CMMS, the Building Owner, Facilities Manager, Maintenance Service Provider and Auditors can easily monitor the progress and obtain KPIs. The CMMS can also raise instructions, keep a tally on faults and expenditure on specific equipment, maintain a spares register and be used to maintain records for electricity meters, water meters and equipment hours-run.

For the successful implementation of a CMMS it is essential that the system is tailored to the facility, the persons utilising the system have had adequate training and on-line assistance is available from system providers.

Further Information

1. AIRAH application manual DA19 – HVAC&R Maintenance
2. CIBSE Guide M – Maintenance Engineering and Management
3. CIBSE Guide to Ownership, Operation and Maintenance of Building Services.

2.5.2 MAINTENANCE MONITORING AND AUDITS

Effective monitoring is essential to ensure that maintenance is carried out in accordance with requirements stated in the maintenance contract. This must be carried out in a structured and methodical manner, using the BMS where possible for monitoring and trending functions. Parameters must be set that are measurable and quantifiable. Utilising KPIs and benchmarks as discussed earlier in this section is an effective method of monitoring the energy and water efficient operation of HVAC Systems.

A maintenance audit must be carried out at regular frequencies throughout the term of the maintenance contract. This can be carried out routinely by the Facilities Manager, although it is recommended that a Maintenance Consultant is used at least annually to ensure an independent approach. The following should be carried out as part of Maintenance Monitoring:

- Checking that logbooks are being maintained in compliance with the maintenance contract
- Checking the service records for major equipment such as chillers, cooling towers and boilers including combustion analysis
- Meeting with site supervisor of Maintenance Service Provider and other staff as necessary
- Reviewing HVAC System and Building KPIs, Benchmarks and performance ratings including NABERS.
- Inspection of HVAC equipment, in particular:
  - Chillers, cooling towers, boilers, pumps and fans
  - Air handling units covering filters, coils, fans, motors and drives
  - Damper operation (e.g. minimum outside, economy cycle and zone shut off)
  - Chilled water and heating water treatment records including corrosion inhibitors.
- Inspection of BMS and controls to include:
  - Plant schedule times including public holidays
  - System control parameters such as temperature, relative humidity and pressure
  - Control sensor calibration
  - Performance of AHUs and VAV boxes through diagnostic screens
  - Performance of VSDs through diagnostic screens
  - Check for software overrides
  - Check on plant KPIs including BMS trends and fault histories.

2.5.3 ENERGY AND WATER METERING

To enable monitoring of building performance it is essential that all energy (electricity, gas and diesel) and water supplies are metered. Utility invoices provide the means to monitor the monthly (or quarterly) energy and water consumption, however, this does not provide the means to analyse how the energy or water is consumed. Most electricity retailers provide half hour time of use (or interval) data upon request, however, this does not provide real time information to monitor systems and to take appropriate action. Sometimes, it could be weeks or months before energy (or water) wastage or faults in power factor correction systems are detected and this could prove very costly. The best option is to have an independent means for monitoring the mains electricity and gas consumption, together with the water consumption. Diesel consumption should also be metered.

Electricity, water and gas utility companies may give permission for their utility meters to be connected to BMS or other systems. If this is not the case, separate metering must be installed downstream of the main meters and connected to the BMS or an independent Energy Management System (EMS).

To enable further analysis of where the energy is being consumed, the installation of sub-metering is essential. The extent of metering depends on the complexity of the building and the reasons for installing sub-meters, which include NABERS, Green Star, on-charging tenants, benchmarking, KPIs, for monitoring wastage (including leak detection) and energy efficiency.

For energy and water efficiency, the following are recommended as minimum requirements.

Electricity: Mains, tenancies, mechanical services switch boards, lifts, chillers, car parks.

Gas: Mains, tenancies, space heating boilers, domestic hot water, kitchens, specialist equipment such as co-generation and tri-generation.

Water: Mains, tenancies, cooling towers, irrigation, car parks.

Diesel: Standby generators.

Thermal Energy Metering: Chillers, boilers, specialist equipment such as co-generation and tri-generation.

Note:

- Electricity meters of the 'smart' type are readily available, with multi-function features that measure kWh, kW, kVA, kVAr, PF and harmonics. These meters have on board memory to store data. Where possible these meters should be connected to the BMS for data storage, analysis and reporting purposes. The advantage with 'smart' meters is that if data communications is lost between the meter and the BMS, the data is still stored in the meter and retrieved by the BMS once communication is restored
- With electricity metering, it is very important to ensure that the current transformers (CTs) are installed correctly and the CT ratios are programmed correctly into the meter. The system must be verified to confirm that readings are accurate (as confirmed by calibration certificates) and this issue is important for NABERS ratings
- Variable Speed Drives (VSDs) have the means to monitor energy consumption of the equipment they serve. Although the levels of accuracy are not high (typically ± 5%), when connected to BMS, they provide a readily available means to set up trends that identify whether equipment is being modulated correctly
- Water, gas and diesel meters are typically of the pulse-count type, where the BMS counts the pulses which are transmitted per unit of water, gas or diesel that passes through the meter. If communications is lost between the meter and the BMS, the consumption that occurs during the lost time is not recorded. For sites that have long distances between the meters and the BMS outstation and for sites where the meter data is very important – such as for NABERS rating purposes it is recommended that data acquisition modules (or outstations) are installed close to the meter, where the data is stored in these units. Upon re-instatement of communications, the BMS will retrieve the lost data
- For all types of metering, it is important to ensure that the BMS is programmed to include any meter correction factors. After the commissioning process is complete, the installer should issue a signed certificate confirming that the system has been verified to be operating within the stated accuracy limits of the meter
- An important issue to consider with gas metering is the pressure conversion factor. The calorific (heating) value of gas depends on gas pressure which is typically reduced after the main gas meter, due to pressure drop in the pipe and also due to regulators installed at various points down stream of the main meter. The factor to convert the gas pressure at the point of measuring, to standard temperature and pressure (STP), the pressure at which the standard calorific value of gas is measured, is important. If this is not determined, and the conversion factor for the main gas meter (as calculated by the utility company) is used, in-accuracies will result. Typically the energy consumption through the gas sub meter being over measured
- Gas metering, especially utility meters, which are to be connected to BMS may require intrinsic barriers to be installed in order to comply with safety requirements.

Further Information

1. CIBSE TM 39: Building Energy Metering – A guide to energy sub-metering in non-domestic buildings. ISBN-10:1-903287-70-7
2. DEWHA: Water Efficiency Guide – Office and Public Buildings. ISBN-06425 52878.

2.5.4 ENERGY AND WATER AUDITS

An Energy or Water Audit is a survey and analysis of a building's energy (or water) consumption to establish how efficiently these resources are being used and comparison of performance with similar buildings where possible. An energy audit also identifies energy saving opportunities as a prioritised list with payback periods. Energy audits are typically carried out in accordance with AS/NZS 3598:2000, which describes three levels of audits ranging from Level 1 to Level 3 depending on the extent of survey and analysis. Typically, for most buildings a Level 1 or Level 2 Audit will suffice, Level 3 being used for large sites where major capital expenditure is envisaged.

A water audit would focus on water savings. There are no accepted standards for water audits although major utility providers operating in the States and Territories have developed templates for carrying out and reporting water audits.

The trigger for an energy or water audit is usually high consumption. For instance, if a building has a poor NABERS energy or water rating, an audit will identify the pathway to enhancing the performance.

A good energy audit requires a thorough understanding of HVAC equipment and electrical systems and a proper analysis is required to ensure that the recommendations will deliver results. Careful selection of the energy or water auditor is important. Experience, proven track record and good references are essential to ensure good results.

2.5.5 TRAINING

To successfully implement energy efficient operation & maintenance it is essential that all Stakeholders are professionally and technically skilled and work as a team to harness the best performance from HVAC Systems.

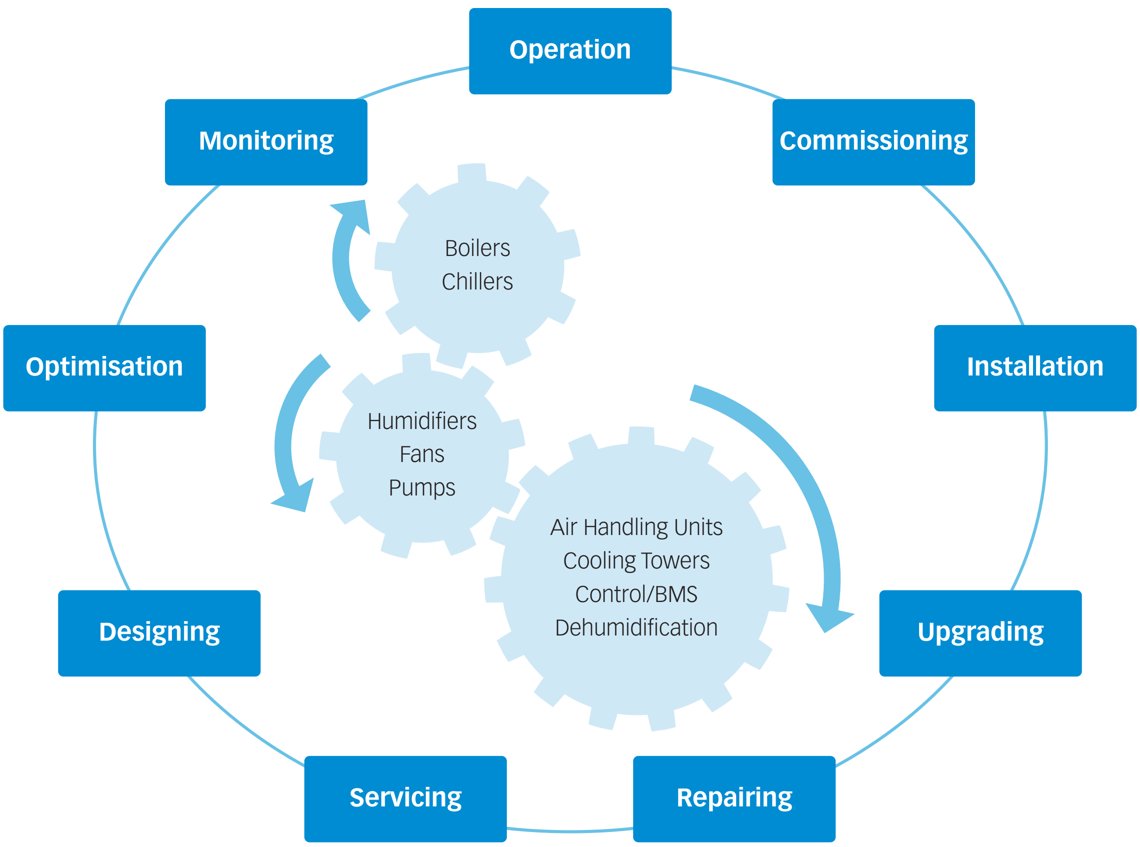
Figure 2.2 shows the various activities required to deliver a good outcome from high performance maintenance.

Maintenance staff will require the necessary HVAC trade qualifications as well as having attended training courses that focus on energy and water efficiency in HVAC Systems. Unless these requirements are contractually stipulated, the HVAC maintenance industry will continue to be cost driven to cut back on training and professional development of technicians, which will result in the industry lacking the necessary skills for enhancing operational efficiencies in buildings. In Australia, numerous TAFE institutions as well as AIRAH offer targeted training for efficient HVAC maintenance and operation.

There are a number of organisations including AIRAH, CIBSE, AMCA and Fmedge that provide training relating to HVAC Energy Efficiency and Water Conservation.

- AIRAH – Energy Efficient Building Operations. www.airah.org.au
- AIRAH – Energy Management Planning
- AIRAH – HVAC Maintenance for Energy Efficiency
- AIRAH – HVAC Water Conservation
- CIBSE has available on-line training towards continual professional development that has content relevant to HVAC energy efficient operation and maintenance. www.cibse.org.au
- The AMCA has available on-line training towards learning and development that has content relevant to HVAC energy efficient operation and maintenance. www.amca.com.au
- Fmedge Facilities Management Training – Vocational Graduate Certificate in Energy Efficiency for Facilities Managers. www.fmedge.com.au
- ASHRAE offer on line courses on numerous HVAC design topics, intended to enhance efficiency. www.ashrae.org.

Figure 2.2 HVAC Systems and Key Activities



3. Building Operation

The correct operation of a building has a significant impact on the performance and efficiency of HVAC Systems.

Building Owners have the most influence for ensuring that buildings are maintained and operated in a sustainable manner and Owners have the potential to motivate and empower all Stakeholders to deliver efficiencies through best practice maintenance and operation. The policies and strategies set by the Building Owners drive the process for setting up the implementation of maintenance contracts and efficiency measures.

Facilities Managers have overall responsibility for managing proper building operation, which covers a range of issues including those that affect the performance of HVAC Systems. To ensure efficient operation of HVAC systems, it is important for the FM to work in collaboration with the Building Occupants and the Maintenance Contractor.

Building Occupants need to be familiar with the systems that serve the tenancy areas as well as those that serve common areas. Occupants need to understand the correct operation of controls for systems including HVAC (supplementary HVAC and base building services) and Lighting (tenancy area and base building). The Building Occupants actions and behavioural patterns should not affect the performance of systems.

With traditional practice, HVAC Maintenance Contractors have had little influence on the operation of HVAC Systems, often they are not given access to the BMS. If system efficiencies are to be gained it is important for **Maintenance Contractors** to be included in certain aspects of building operation and given access to monitor HVAC systems and to make limited changes to system operating parameters, through the BMS.

Often, Stakeholders are not aware of the responsibilities they carry towards achieving efficient operation of buildings. A team effort is necessary, with good communication between the different Stakeholders to ensure improved results are accomplished.

3.1 Building Owner

For a Building to be operated efficiently, it is essential for the Owner to ensure the following:

- All Stakeholders including the Facilities Manager, Occupants, and Maintenance Service Providers are aware of the strategies for efficient operation and work collaboratively to achieve efficient operation
- The Facilities Manager has adequate resources including training to accomplish his responsibilities
- The Building Occupants have the necessary information such as Building User Guides and Tenancy Fit-out Guidelines
- Good communication channels exist between all Stakeholders and there is regular feedback on important aspects of Building Operation and KPIs
- KPIs are regularly monitored and corrective action such as re-commissioning and fine tuning is carried out where necessary to improve building performance
- Lease conditions don’t stipulate wasteful temperature or humidity requirements. Where necessary, these should be re-negotiated with the building occupants.

Note: It is important to ensure that control parameters for the building such as temperature, relative humidity and operating hours are not wasteful in energy consumption. Suitable temperatures for operation are typically 21–22°C in winter and 23–24°C in summer. However, depending on other aspects such as the building façade, type of HVAC system, relative humidity (RH) and the ‘tolerance’ levels of occupants, winter temperature may be reduced to 20°C and summer temperature elevated to 25°C, whilst maintaining levels of comfort acceptable to most occupants. For every 1°C lowering of winter temperature and 1°C elevation of summer temperature, the energy consumption for heating and cooling reduces by 5–10%.

For most office type applications the relative humidity can be allowed to 'float' between 35–60% RH and perhaps even beyond, depending on the building, its location and the type of occupancy.

Areas such as lift and entrance lobbies and other transient areas where occupants spend relatively short periods of time can typically tolerate wider temperature deviations when compared with other areas. After hours operation should be limited to one hour per activation.

Air conditioning requirements for areas such as lift motor rooms and server rooms must be carefully evaluated to ensure that these areas are not wastefully 'over serviced'.

3.2 Facilities Manager

The following items should be undertaken by the Facilities Manager to ensure correct building operation:

- Confirm that the BMS is scheduled to exclude HVAC operation during public holidays and the systems operate in accordance with the agreed service times
- Ensure after-hours operation of central services can only be activated by authorised personnel and the durations recorded. This is important for invoicing and NABERS ratings
- Adjust the BMS controls to avoid over-heating and over-cooling of the building spaces, beyond agreed service conditions, in leases
- Minimise HVAC usage for transient areas such as lobbies, wherever possible
- Designate responsibility and set-up protocols for adjusting BMS scheduling and HVAC System control settings. Regularly review and adjust to specific requirements for the different areas of the building
- Ensure that Building Occupants do not use plug in type electrical space heating or cooling appliances
- Ensure automatic door closers are functioning properly and seals are in good condition
- Check that exhaust fans are switched off when the building is unoccupied unless continuous operation of particular systems is essential
- Set-up purchasing policies to consider energy and water efficiency when replacing existing equipment and plant
- Prioritise service call outs to Maintenance Contractors for faults that waste energy and/or water
- Engage with all parties concerned to ensure successful results. Stakeholders range from the Building Owner, the Occupants, the Maintenance Service Provider and may even include the Cleaners and Security Guards who have an important role to play with ensuring that equipment is switched off after normal working hours.

The monitoring of HVAC energy and water consumption is highly desirable to identify potential wastage. This may be carried out for the whole building, individual tenancies or particular areas. Examples of how this can be achieved are as follows:

- Use utility metering, especially half hour time of use electricity metering where available, to monitor energy consumption of HVAC Systems. This data is typically available free of charge from utility suppliers and analysis of this information provides useful indicators such as wasteful operation after-hours (e.g. public holidays and overnight). Where necessary, install additional sub-metering to enable monitoring and trouble identification of wastage
- Where a BMS is installed, use the system to monitor the energy and water consumption. Set up trends and alarms on the BMS to report any spikes or unusual consumption patterns, which is known as *exception reporting*
- Set up KPIs for monitoring the performance of HVAC Systems with regards to energy and water consumption and to compare with other similar buildings and available benchmarks
- Monitor the KPI trends to evaluate the impact of measures such as the installation of new equipment, alterations to control strategies and changes to operational and maintenance practices.

3.3 Occupants & Tenants

It is important that the actions and behavioural patterns of Building Occupants do not cause adverse effects to the performance and efficiency of HVAC Systems. Following are some of the key issues that can assist Building Occupants with ensuring correct operation:

- Carefully select and purchase office equipment that complies with current Energy Star requirements. Visit www.energystar.com.au. for more information. Office equipment such as computers monitors and printers have Energy Star features which shut down power to equipment when on standby mode and IT staff should be instructed to enable these hibernation features. A Computer (PC) left operating continuously, rather than only operating when necessary will result in the emission of about one tonne of CO_2 wastefully into the atmosphere, each year. Equipment such as refrigerators, supplementary HVAC systems, dishwashers and TV's must comply with current MEPS (minimum energy performance standards) and the energy labelling scheme will assist to find efficient equipment
- Check that staff are familiar with the contents of the Building User Guide (refer to Section 4.4). If there is no Building User Guide available, request one from the Facilities Manager
- Encourage staff behaviour that reduces energy wastage and discourage staff behaviour that wastes energy
- Ensure that Tenancy Fit-out Guidelines (refer to Section 4.5), issued by the Building Owner are observed during renovations and upgrades
- When installing space partitioning during office fit-outs, ensure the use of natural lighting is not obstructed and the operation of HVAC Systems is not affected
- When carrying out tenancy fit-outs, ensure that the lighting power density does not exceed BCA Section J requirements and complies with the tenancy fit-out guidelines. Lighting produces heat, which must be removed by air conditioning systems, which wastes energy
- Make staff aware of key features associated with the correct operation of the HVAC and lighting systems
- Carry out awareness campaigns and install signage at Lighting and HVAC after-hours switching controls, encouraging staff to switch off systems which are not required. Apart from saving tenancy energy consumption, this also reduces heat emissions to be removed by the base building air conditioning systems, thereby conserving energy
- Ensure that staff do not operate personal heaters and other appliances. This could significantly increase energy consumption of the tenancy and also affect the operation of the base building HVAC Systems
- Where possible, staff working after-hours such as over weekends should be encouraged to use areas that are served by supplementary HVAC Systems. Often, meeting rooms have such systems installed, which are more economical and efficient to operate, rather than using the base building HVAC Systems – which is expensive and inefficient when operated to serve small areas
- Switch off non-essential office equipment when not in use, which will reduce the tenancy energy consumption. Also, equipment produces heat when in operation, which has to be removed through the operation of air conditioning systems, which wastes energy
- Ensure windows and doors are kept closed when the building is unoccupied during the heating or cooling seasons. Report any gaps in sealing which cause air leakage and draughts to the Facilities Manager
- During summer – close window shading devices to reduce air conditioning loads. During winter – when it is dark outside, close window shading devices to reduce heat losses through radiation
- Check that HVAC Systems are switched off after-hours and that cleaning staff do not have access to operate HVAC Systems wastefully
- Check that the use of lighting is minimised by cleaning staff, after-hours. Lighting kept in operation overnight emits heat, which has to be removed by the HVAC Systems
- Ensure that security guards on regular patrols after-hours do not automatically (and unnecessarily) switch on lighting circuits through motion sensors. Buildings are provided with a background level of emergency lighting and where possible, guards should use torches and only switch on lights when necessary
- Engage with all parties concerned to ensure successful results. Stakeholders range from the Building Owner, the Occupants, the Maintenance

Service Provider and even include the Cleaners and Security Guards who have an important role to play with ensuring that equipment is switched off after hours.

3.4 Maintenance Service Provider

It is important for Maintenance Contractors to proactively identify any potential issues that affect HVAC Systems due to poor operation. For this to be cost effective whilst adding value to their work, Contractors need to operate smartly, using existing windows of opportunity and leveraging off existing diagnostic tools where ever possible.

Examples of working smarter include:

- When making scheduled visits to tenancy areas, for reasons such as cleaning air filters in fan coils, visually check the room temperature sensors for issues such as tenant office equipment either covering the sensors or affecting their readings with heat, such as from office equipment located directly underneath the sensors. Also check for the presence of portable heating equipment (which should be discouraged), correct operation of blinds/windows/doors and the control of supplementary HVAC Systems. It is essential that maintenance staff are properly trained and instructed to spot these opportunities. A check list should be issued and sufficient time allocated for the task. It is also important for Maintenance Staff to regularly meet with a designated person on each floor (or tenancy area) and to discuss any relevant issues
- The BMS can provide a wealth of information on issues that affect the efficient operation of HVAC systems and this topic is covered in Section 6.11. Maintenance Contractors need to obtain the necessary level of password access into the BMS to enable monitoring of HVAC Systems through setting up trend reports, KPIs, exception reports and alarms. The Maintenance Contractor should also be able to make basic adjustments to system parameters such as plant scheduling, and this should be carried out in partnership with the Facilities Manager. Protocols must be agreed with regards to the level of competency of the BMS Specialist engaged by the Maintenance Service Providers, the level of BMS access permitted, the level of changes allowed to be made and the documentation required by the Facilities Manager when any changes are made to the BMS.

Further Information

1. ESD Operations Guide for owners, managers and tenants – DEWHA:ISBN 0 642 553 505
2. Tenant Energy Management Handbook – SEDA: ISBN 0 7313 9740 1
3. Energy Efficiency in Government Operations – Department of the Environment and Heritage: ISBN 192 1120 827.

4. Documentation

4.1 General

It is essential to maintain and update the important documentation related to a building and its services, from design through to demolition stages. Good documentation is essential for a number of reasons including health & safety, maintenance & operation, financial accountability and for achieving energy and water efficiencies.

During the lifetime of a building there is inevitable change amongst the key Stakeholders including Facilities Managers, Maintenance Contractors and Building Occupants. Changes are made to the building layout (including tenancy fit-outs) and HVAC Systems including replacement of equipment, maintenance & operation procedures and control strategies. It is essential for these changes to be documented and key Stakeholders to have ready access to information when required.

In some premises, it is likely that important information including operating & maintenance manuals and equipment schedules (Asset Registers) are either missing or out of date. It is important for Facilities Managers to make best endeavours to obtain this information, either through contacting the original designers and/or installers or contacting the various equipment suppliers and collating the information with the assistance of the Maintenance Contractor or by engaging a Maintenance Consultant.

For older buildings, it is likely that information is available in the form of hard copies. For new buildings, information should be available in the form of hard copies and in electronic format. With the increased use of 3-D modelling and Building Information Modelling and Management (BIMM) systems, it is possible to represent the necessary information for maintenance in the form of virtual plant rooms, with 'objects' incorporating key data including operating parameters, routine maintenance and spare parts for the equipment installed.

This section describes the key documents that are required for the efficient operation & maintenance of HVAC Systems.

4.2 Operating & Maintenance Manuals

Easy access to Operation & Maintenance (O&M) manuals is essential for Maintenance Service Providers to obtain the necessary information. Manuals must include information on the following:

- Design intent for HVAC Systems and operating parameters – including energy and water efficiency measures
- Description of the systems that are installed to serve the different areas
- Manufacturer's data including servicing schedules and recommended spare parts listings
- Maintenance schedules for HVAC Systems and equipment
- Functional description and control schematic drawings for the BMS
- As installed drawings, including location of key components that require maintenance and access
- Commissioning data, including settings on regulating valves (pressure and flow)
- Design and installation certification, with reference to applicable regulations and standards.

In addition to proper (structured) commissioning of HVAC Systems, the importance of Building Tuning over a period – typically twelve months covering seasonal climatic changes, is recognised as being essential for HVAC systems to deliver optimum efficiencies. The O&M manuals should be live documents that keep track of this process.

It is important for O&M manuals to include the necessary data for monitoring the operational efficiencies of equipment, covering parameters such as recommended pressure drops across air filters and heat exchangers, approach temperatures for chillers and boilers, and coefficients of performance and KPIs with regards to energy and water consumption.

O&M manuals are too cumbersome for use by Building Occupants, hence, there is a need for simplified information to be presented in Building User Guides – as described in Section 4.4.

4.3 Maintenance Log Books

Maintenance log books are a mandatory requirement under Health and Safety Regulations for equipment such as cooling towers, pressure equipment and large boilers. However, even where there are no regulatory requirements, it will be beneficial to set up maintenance log books which are dedicated to equipment that have a significant impact on energy and water consumption.

Log books for equipment such as chillers, large boilers, co-generation and tri-generation equipment should have information specific to the correct operation & maintenance of such equipment and would, therefore, be beneficial to all Stakeholders who have an interest in monitoring the performance of equipment. The recommended format for such equipment log books would be available in the HVAC equipment manufacturers O&M instructions.

Maintenance log books can also be set up at a high level – serving an entire facility or a plant room. A site (or high level) log book would keep a record of information such as service visits made by Maintenance Staff noting the name of staff member, the date and time of visit, the nature of planned or reactive maintenance carried out, any control settings altered and any other comments that may be useful to the Facilities Manager or other Maintenance Staff. Such a record will assist all parties associated with the management of maintenance contracts to monitor the nature and frequency of site visits. Traditionally, only issues that are likely to cause health and safety concerns and Tenant complaints have been recorded in maintenance log books, however, it is important to expand this to include potential issues related to energy and water wastage.

4.4 Building User Guides

A Building User Guide is a document that provides Building Occupants, Facilities Managers, Maintenance Contractors and Energy Auditors the key information necessary to operate a building efficiently.

The Building User Guide must be readily available to Building Occupants and it must be referenced in tenancy contract documents. It is recommended that new staff, as part of their induction process are required to familiarise themselves with the important operational features and efficiency measures (e.g. automatic lighting control systems or after hours operation of HVAC System) in the building.

Building User Guides must cover the following information:

- Clear description and operating instructions for all systems installed in buildings to which Building Occupants have access. These include lighting, window shading devices and supplementary (Tenant installed and operated) HVAC Systems
- Information on the design intent for HVAC Systems including scheduled times of operation and design temperature conditions
- Guidelines on the use of after-hours HVAC, including whether to use base building services or to use designated areas that have supplementary HVAC Systems which are likely to consume less energy and be much cheaper to operate
- Instructions for the correct operation of any specific energy and water saving features installed in the building
- Contact details of a nominated person for reporting problems with HVAC Systems, energy and water wastage and for making suggestions for improving a building's sustainability
- Information on the building's energy and water metering and sub-metering systems, together with recording systems
- Target environmental performance ratings (such as NABERS) and KPIs such as monthly kWh/m^2 and MJ/m^2 for energy consumed by HVAC services and ML/m^2 for water, to enable effective monitoring and targeting.

Further Information:

1. www.works.qld.gov.au/downloads/qgao/oamf/4_sample_bug.pdf
2. CIBSE TM31: Building Log Book CDROM Kit
3. Good Practice Guide 348 Building Log Books – A User's Guide: www.actionenergy.org.uk

4.5 Tenancy Fit-out Guidelines

The equipment installed and operated by a Tenant (or Building Occupant) can have a significant impact on the efficiency of base building HVAC Systems. Guidelines must be included as part of lease agreements to ensure that Tenancy fit-outs do not affect the base building systems that could have a negative impact on energy consumption. Tenancy fit-out guidelines typically cover contractual issues only and are light on issues that affect building efficiency and performance. Important issues to consider include the following:

- Tenants, their Design Consultants and Installation Contractors must seek approval from the Facilities Manager prior to carrying out any work that is connected to the base building systems or, could affect the performance of the base building HVAC Systems
- Any alterations carried out within the tenancy areas must not exceed the design lighting or equipment power density within the fit-out, as stated by the Designer as part of the original design intent for the building. Heat given off by tenancy equipment and lighting has to be removed by the base building HVAC System and will have an impact on the energy consumption of the base building
- Occupants must not make changes that affect the efficiency of automatic lighting control systems
- Installation of supplementary HVAC Systems powered through the Tenant's distribution boards (rather than base building) to serve any areas that have HVAC loads that are higher than the designed base building loads
- Supplementary HVAC Systems must integrate with base building systems rather than counter-acting them. When installing supplementary HVAC Systems, their controls must be interlocked to prevent the Tenants systems fighting against the central system. As an alternative, the base building services that serve these areas must be disconnected, with the approval of the Facilities Manager
- Installation of motorised actuators on dampers and valves for all Tenants' supplementary equipment that is connected to base building services. This includes Tenants supplementary outside air, exhaust air and condenser water systems. The actuators should automatically shut when these systems are not in operation, thereby reducing the energy consumption of the central systems, through the operation of VSDs that reduce the speed of the motors that drive these systems. Effective time of use controls such as occupancy sensors or self-timers should be provided to ensure that Tenants do not operate these systems longer than needed
- When Tenants HVAC equipment such as packaged water cooled HVAC Systems are installed, they should not have high pressure drops on their heat exchangers, which would add to the index run pressure drop and increase energy consumed by the central systems. Equipment connected to the Tenants' condenser water loop are of particular importance to consider
- Ensuring that Contractors carrying out office fit-outs do not alter the characteristics of base building HVAC Systems. Examples are the partitioning of areas that affect HVAC zoning and/or return air paths, the 'squashing' of flexible supply air ducts and/or lengthening them to an extent where the index pressure drop on the supply air fan is increased and the system wastes energy when fan speed has to be raised in order to overcome these restrictions
- It is important not to damage or relocate any temperature or pressure sensors (such as duct pressure sensors) that control base building systems
- Avoid positioning office equipment (especially those that give off heat), in locations where they are likely to interfere with base building controls such as temperature sensors. Where this is not possible, the Facilities Manager must be notified and the sensors re-located.

4.6 Asset Register

It is essential to compile a comprehensive asset register prior to setting up a maintenance contract. This ensures that all parties are aware of the equipment that must be covered in the contract, therefore, reasonable estimates for the necessary resources and costs can be compiled.

The Asset Register must include all HVAC equipment that requires maintenance. Equipment must be given a unique asset number with a robust label attached in a clearly visible location. As equipment is repaired or replaced, the label and the asset register must be updated. Bar code type systems are available, which makes this task easier. An Asset Register can be simply maintained utilising a spread sheet/database system using office type software or can be an integral part of a sophisticated computerised maintenance management system (CMMS) for a large facility.

It may be necessary to obtain professional assistance from a specialist Maintenance Consultant to carry out a thorough survey of the building and compile the Asset Register, especially if factors such as equipment condition and performance are to be captured. Once the Asset Register is established and a maintenance contract is set up, the responsibility for updating the Asset Register can be passed on to the Maintenance Contractor, with regular QA checks performed (either by the FM or the Maintenance Auditor) to ensure conformance.

It is important for HVAC equipment in an Asset Register to be given an Environmental Impact Rating (EIR) that quantifies their potential impact on energy and water consumption, as explained in the next section. An EIR will enable Facilities Managers and Contractors to get an overall picture about the potential impact that HVAC equipment have on energy and water consumption and to prioritise opportunities for upgrade.

An Asset Register typically includes the information in Table 4.1. However, with the availability of electronic systems, including CMMS and hyperlinks, it is possible to have much more information such as drawings and manufacturers information available on the system.

Table 4.1 Information in Asset Register

Information	Comments
Asset Number	A unique identifier or reference number.
Description	E.g. PHWHP 1. Primary hot water heating pump P1. (As referenced in as-built plant room schematic drawings).
Quantity	Typically 1, but multiple small items may be designated under one asset number. E.g. 12 thermostatic radiator valves in a room could be given one asset number, with a suffix/1-n.
Manufacturer	Include contact details of supplier if possible.
Model	As supplied by the manufacturer.
Serial No.	As supplied by the manufacturer. Also include any particular modifications carried out. E.g. Pump impellor trimming or fan pitch adjustment.
Misc. Information	E.g. Installation date, cost, condition, major overhaul dates.
EIR	See section below.

4.7 Environmental Impact Rating (EIR)

An Asset Register typically has a large number of items of equipment, which could range into hundreds or thousands depending on the size of a building. For the purposes of assessing the potential environmental impact of key HVAC equipment that consume energy and water, it would be beneficial to include an index (or a metric) against each item representing the potential to gain efficiency improvements from the equipment through maintenance, repairs or replacement.

Such a system would enable interested parties including the Facilities Manager and Maintenance Contractor to rank the HVAC equipment in order of making potential improvements to efficiency, thereby assisting with the identification of good opportunities for implementation.

It must also be noted that any significant opportunity to save energy and water in a HVAC System can also be a potential source for energy and water wastage. E.g. the energy saving potential for a poorly operating economy cycle to be improved for saving energy, is the same as the potential for a properly operating economy cycle to be poorly maintained and to waste energy.

Factors to consider when ranking equipment for energy consumption are:

- The power rating of the equipment, which may be assessed through methods ranging from the nameplate rating through to de-rating the nameplate rating by a loading factor: E.g. 0.7–0.85 could be typical for an electric motor driving a fan or pump at fixed speed. More accurate information should be available through VSDs where they are installed (through high level interfaces to BMS or readings recorded at different times) or where sub-metering is installed
- The usage factor. This takes into account whether the equipment operates continuously when enabled (e.g. a fan) or cycles intermittently (such as a refrigeration compressor or a burner fan on a boiler)
- The efficiency of the equipment which could range from very high to low, depending the type, the age/condition and the mode of operation
- The operating hours per year. This could range from very low – for equipment such as stairwell pressurisation fans which are only operated for routine testing purposes, to very high (8,760 hrs./y) for equipment such as Tenants condenser water pumps. Typical air handling systems operate 2,500–2,800 hrs./y, depending on the extent of after – hours usage.

Based on the above factors, the energy consumption, energy cost and greenhouse gas emissions can be calculated by using a simple spread sheet analysis and this information can be linked to the Asset Register. This would enable the equipment to be ranked in order of energy consumption, energy cost or greenhouse gas emissions (including potential NABERS stars).The aim is to rank the equipment, in the order of their potential to consume energy, thereby giving the means to identify priorities for repair or upgrade.

5. Financial & Environmental Evaluation

5.1 Introduction

Due to time and cost constraints, pressures often exist to select maintenance options and strategies that are based solely on capital costs, as it is the easiest to quantify and has the most immediate financial implications. However, this approach is unlikely to deliver the best long term outcome for many of the Stakeholders. The long term benefits from best practice maintenance and operation in buildings are now well accepted and these are described in Chapter 1 of this document. Investing some additional time on simple economic analysis can lead to more informed judgements and deliver significant financial benefits over the subsequent years.

During the process of making routine site visits to carry out maintenance, the HVAC Maintenance Service Provider is best placed to identify opportunities that can reduce energy and water consumption. These opportunities range from repairing an existing item of equipment, replacement with like for like, upgrading with a more efficient model and enhancements to the system to improve efficiency and performance.

The correct analysis and presentation of the potential benefits and cost effectiveness of these measures to the Facilities Manager is essential, if the best option for long term benefits is to be understood and appreciated. An assessment of potential environmental benefits, which would enhance the 'green performance' of the building and deliver the Building Owners objectives as stated in the Environmental Policy, is also important. A presentation which quantifies the potential benefits and offers a credible business case is likely to improve the chances of gaining the Facilities Managers approval to implement these measures. This approach presents opportunities for the Maintenance Contractor to add value to an existing contract and to achieve a 'win-win' situation.

This section outlines some of the methods available for Maintenance Contractors to assess the cost effectiveness and environmental outcomes, and to assist Facilities Managers achieve better economic and environmental benefits from measures that reduce energy and water consumption.

5.2 Simple Payback Period

This is the most basic of economic analysis methods and it is only applicable for situations where a reduction in operating costs relative to business as usual (or some other alternative) will be achieved by a system repair, replacement or upgrade. This method estimates the number of years it takes to recover capital cost, but does not take into account savings beyond that. Therefore, this analysis does not calculate return on investment (ROI) or any tax savings due to depreciation.

The simple payback period is calculated as:

Payback Period (Years) = Capital Investment ($) / Annual Savings ($)

5.3 Net Present Value

A Net Present Value (NPV) calculation is the recommended method for identifying the economic outcome of an action and the optimal outcome from a number of options. As the name indicates it calculates the net value (benefits minus costs) of an action in today's dollars so that fair and direct comparisons can be made.

The major benefit of this tool is that it acknowledges the time value of money; that is $1 today is worth more than $1 in a year's time. The time value of money is represented in the calculations by a 'discount rate' which reduces the value of money in future years by a certain rate per year (usually in the range of 5–10%/y depending on the application).

The ability to include discount and inflation rates as well as other factors as required, gives a good indication of the economic outcome of an action. However, as these rates are assumptions of future trends they inevitably include a degree of uncertainty and the opportunity could exist for these assumptions to be manipulated to support a particular position.

There are a number of online NPV calculators which can assist with assessments.

Further Information

1. CIBSE Guide M: Maintenance Engineering and Management: ISBN 978 1 903287 934.

5.4 Internal Rate of Return

Internal Rate of Return (IRR) is similar to NPV, however, rather than attempting to calculate a monetary value as the output it simply identifies the discount rate at which the NPV is zero, therefore, eliminating one of the assumptions required for NPV calculations.

IRR has benefits over NPV. However, it requires some understanding of the underlying economics for the output to be meaningful and is, therefore, not always easy to apply.

5.5 Life Cycle Analysis

Life Cycle Analysis (LCA) is a detailed analysis technique that aims to quantify all environmental costs – past, present and future, attributable to an action or product whether they are direct or indirect. This goes beyond simply maximising the economic return to the Building Owner. LCA is more altruistic in nature, aiming to minimise environmental costs rather than costs borne by the Building Owner.

Due to the detailed, time-consuming and costly nature of conducting a LCA it is unlikely to be used in the development of HVAC maintenance strategies. However, the benefits of a positive LCA should be understood and products or services that have a LCA conducted for them and have achieved a positive result should be given preference in the procurement process.

When presented with a LCA the scope and goals should always be scrutinised as they are critical factors and the outcomes are largely meaningless unless presented in context.

Note: Life Cycle Analysis is not related to Life Cycle Cost which is referred to in the next section.

5.6 Benefits of Economic Analysis

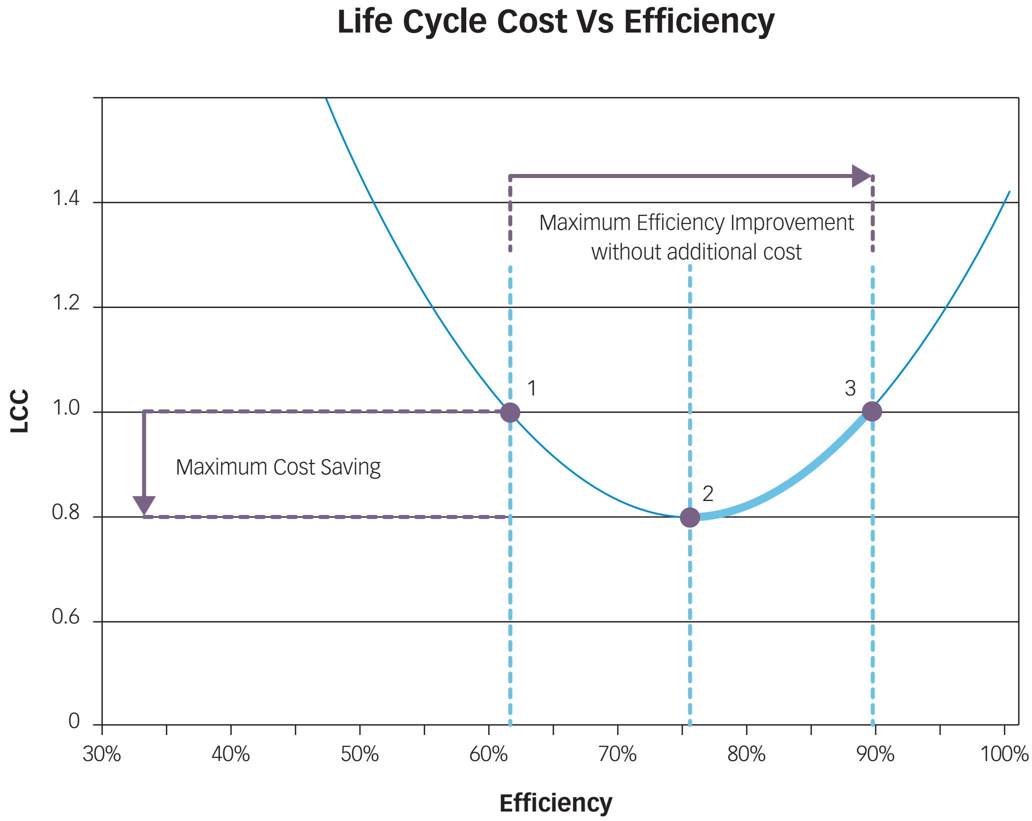
Conducting NPV calculations requires extra effort, however, the potential benefits could be substantial as shown in the figure below which plots efficiency against Life Cycle Costs (LCC). NPV has an inverse relationship with LCC, NPV increases as LCC decreases.

Figure 5.1 (on page 34) illustrates that for a hypothetical building operating at point 1 efficiency can be improved while increasing the NPV until point 2. NPV analysis aims to result in operation at point 2.

Efficiency can continue to be improved until point 2 without costing any more than 'business as usual'. There will always be a point where the LCC cannot be reduced any further (point 2) because the capital cost of increasing efficiency is higher than the present value of the possible savings.

The blue region from point 2 to point 3 is generally the best region to operate a building, however, in some cases increasing efficiency beyond this range is required to achieve a building performance rating that is desired or has been committed to. The installation of co-generation, tri-generation or renewables might fall within this category.

Figure 5.1 Life Cycle Cost Vs. Efficiency



5.7 Environmental Evaluation

When evaluating the benefits of high performance maintenance contracts and specific energy and water efficiency upgrades, potential environmental benefits must be assessed, in addition to the financial benefits.

The potential enhancement to a building's NABERS energy and water ratings can be assessed by using the online calculator freely accessible on the NABERS website. Any existing rating would be available from the last accredited NABERS rating carried out on the building. If such a rating has not been previously carried out for the building, then the Facilities Manager or the Maintenance Contractor can carry out an informal NABERS assessment using the on line calculator. Key information required is the location (post code) of the site, the electricity/gas/diesel/water consumption data for the previous 12 months, information regarding the net lettable area (which should be available from the Facilities Manager) and the hours of service provided by the HVAC systems for the tenancies, including after-hours operation.

Once the potential reductions to energy and/or water consumption through efficiency measures have been estimated, it is a simple task to input the revised figures to the NABERS online calculator and to obtain an assessment of the improvement to the rating. It must be noted that the NABERS ratings increment in steps of 0.5 star bands, however, the NABERS calculator will display the improvement gained within a 0.5 star band.

It may also be necessary to estimate the savings of greenhouse gas emissions, through the implementation of measures to enhance efficiency. This information can be used for reporting, and also in news letters to announce the success of 'green measures' implemented. Once the potential energy savings in kWh or MJ are assessed, the equivalent CO_2 emissions can be obtained from www.climatechange.gov.au under National Greenhouse Accounts (NGA) Factors, the current figures for electricity consumed from the grid and for natural gas and diesel are shown in Table 5.1

Table 5.1 Emission Factors

State, Territory or Grid Description	Emission factor kg CO_2–e/kWh
New South Wales and Australian Capital Territory	1.06
Victoria	1.35
Queensland	1.00
South Australia	0.81
Western Australia	0.93
Tasmania	0.33
Northern Territory	0.75
Fuel Combusted	**Emission factor kg CO_2–e/GJ**
Natural Gas	51.3 (0.18KgCO_2–e/kWh)
Diesel	69.5 (0.25KgCO_2–e/kWh)

Further Information

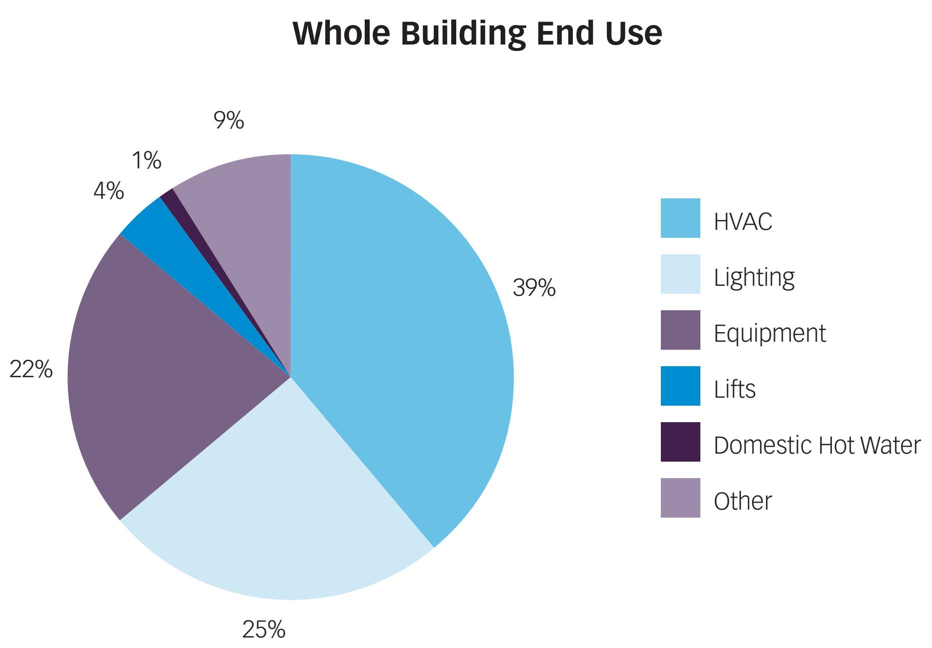
1. www.climatechange.gov.au
2. www.nabers.com.au

6. HVAC Equipment & Efficiency

6.1 Introduction

HVAC electricity consumption forms a significant amount of total building consumption – typically around 40% of total building consumption and around 70% of base building (i.e. landlord) electricity consumption, as shown in Figure 6.1.

Figure 6.1 Typical Energy Consumption Breakdown in an Office Building

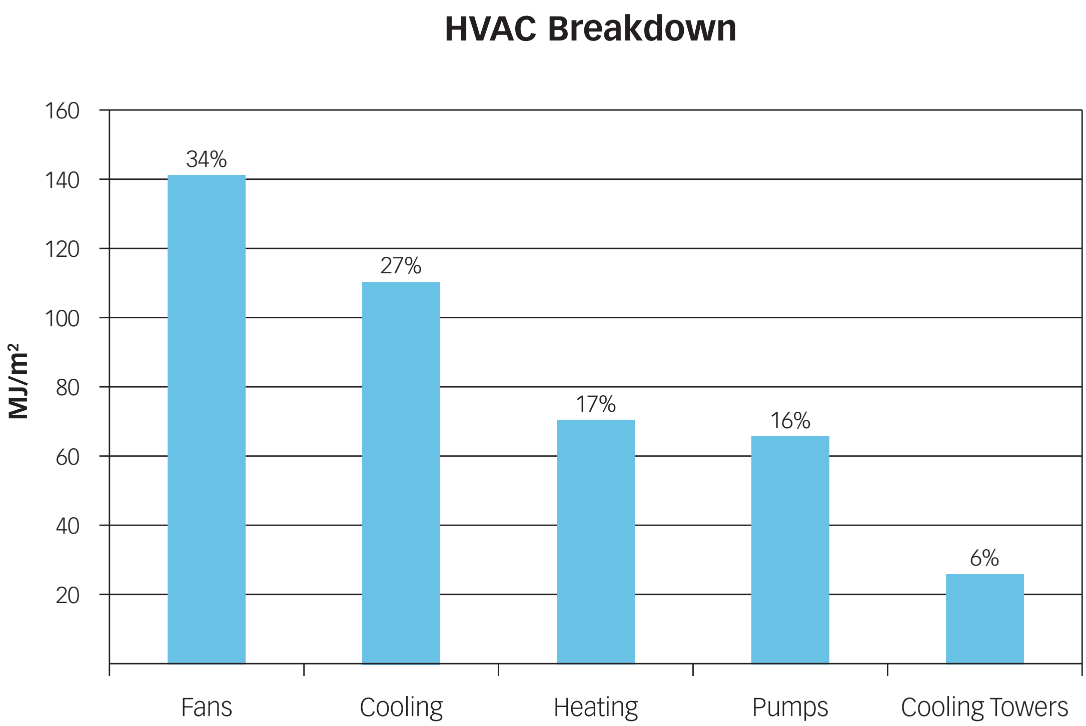


Within HVAC there are a number of key end uses, including:

- Fans: for air circulation and ventilation
- Cooling: most frequently, the energy use of chillers for the production of cooling via chilled water, but also the use of direct expansion cooling systems such as packaged air-conditioners
- Heating: most frequently, the energy use of boilers for the production of hot water for heating, but also often the use of electric heaters for zonal reheat
- Pumps: for the circulation of heating hot water, chilled water and condenser water
- Cooling towers: the energy used for the operation of cooling towers for heat rejection, being primarily the cooling tower fan energy.

Figure 6.2 illustrates a typical office building's consumption for these items.

Figure 6.2 Typical Energy Consumption Breakdown in a HVAC System



There is a great deal of variation amongst different buildings, which is a consequence of numerous factors, including:

- Differences in efficiency. This can have a radical impact on any figure; for some buildings the before-and-after consumption of an individual end-use following efficiency upgrade can vary by as much as a factor of five or more. This is particularly true of fans, which are highly non-linear, and gas, which is often very inefficiently used and, thus, a substantial source of savings
- Differences in building loads caused by building shape, orientation and location. The physical characteristics of the building have a significant impact on building loads and particularly the balance between heating and cooling. For instance, a building with very limited north and west glazing will generally have lower than average cooling loads, while a building with a large unshaded west facade will have high cooling loads, particularly in the afternoons
- Differences in HVAC system type, which can significantly alter the distribution of energy between different end-uses. The energy use shown in Figures 6.1 and 6.2 is generally typical of the more common air-based air-conditioning systems such as variable air volume systems, typically with water cooled chillers. Changes in system type can produce significant changes in distribution. Examples include:
  - Constant volume air-conditioning systems – or variable volume systems with poor air-volume controls – have far higher fan energy – upwards of three times that of an equivalent well tuned variable volume system
  - Economy cycle – most buildings with air-based air-conditioning systems in temperate climates have economy cycles, which use outside air to provide “free” cooling when conditions permit. This strategy is particularly effective in cooler climates (Melbourne, Adelaide and Canberra), but is still useful in Sydney. Buildings in these climates that do not have an economy cycle will typically have significantly higher cooling energy, as the cooling has to be provided year-round by the cooling system rather than using cool outside air
  - Heating – heating in most buildings is used for two purposes, being seasonal heating (i.e. heating because it is cold outside) and reheat, which typically is used as a local adjustment to cooling. Constant air volume systems use a considerably larger amount of reheat than variable air volume systems in general; high reheat use is a classic signature for failure in a variable air volume system
  - Chilled beams – chilled beam systems use water as the primary means of delivering

cooling around the building. As a result they typically have far lower fan energy, but also often have a greater amount of cooling energy due to the lack of an economy cycle

  - Air-cooled chillers – air cooled chillers are significantly less efficient than water cooled chillers. As a result the cooling energy for a building using air-cooled chillers is roughly twice what would be expected for the same building with water cooled chillers.

- Differences in climate. While it is true that climate has an impact on office buildings, the scale of effect is generally far smaller than believed. This is because the climate only really impacts on the perimeter of the building; the centre zone is protected from outside influence by the perimeter zone. Thus, while it is true that a building in Melbourne will typically have less cooling and more heating than a building in Sydney or Brisbane, any of the various factors discussed above may operate such that the building has more cooling than many buildings in the warmer climates. Nonetheless, it is reasonable to consider that only the colder capitals have significant genuine heating loads in office buildings; the heating loads in Sydney are very small and essentially non-existent for Brisbane. Cooling will also increase on average from cooler climates to warmer climates. Other end-uses, such as fans and pumps are far more strongly affected by design and operational variables than climate.

The main purpose of HVAC Systems in commercial buildings is to maintain comfort conditions for the occupants, the main criteria being space temperature (20–24ºC) and relative humidity (40–55%RH). Across Australia there is a wide range of climatic conditions, therefore, the HVAC Systems installed are different. Also, buildings of different vintage tend to have different types of HVAC Systems. However, there is commonality amongst the major energy consuming equipment within these HVAC Systems.

This Chapter describes the main components of HVAC Systems. Information is given regarding important features of equipment together with operational & maintenance issues that have a significant impact on energy and water consumption. It is recommended that this Chapter is read for background information by all users of this Guide. Additional technical information should be obtained from relevant sources including manufacturers of equipment, by those actually implementing the technical measures recommended.

Techniques associated with energy and water efficiency are continuously evolving. Keeping abreast of emerging technology and understanding the operating principles of HVAC equipment and BMS controls will improve the chances of successfully implementing energy and water conservation measures and decrease the potential to make mistakes. The information in this chapter is supplemented in checklist forms in Appendices B through to H.

Further Information

1. CIBSE Guide – Energy Efficiency in Buildings: ISBN 0 900953 86 1
2. Energy Efficiency Manual – Donald R Wulfinghoff: ISBN 0 9657926 7 6
3. AIRAH Application Manual DA19: HVAC&R Maintenance: ISBN 0 949436 39 9
4. AIRAH Application Manual DA8: HVAC&R An Introduction: ISBN 0 949436 24 0.

6.2 Chillers

A chiller is a machine that produces chilled water that is used for air conditioning in buildings. Chillers are expensive items of plant and they consume significant amounts of energy in commercial buildings, therefore, correct maintenance & operation is important.

Types of chillers in common use are:

Vapour Compression Chillers – The most commonly used type. This type of machine uses the vapour compression refrigeration cycle for producing chilled water and electricity is consumed by the motor that drives the compressor of the chiller. These machines can be further categorised into air cooled chillers – where the machine rejects heat to outside (ambient) air, or water cooled chillers – where heat rejection is to water, typically through cooling towers.

Absorption Chillers – This type of machine uses thermal energy (heat), typically by burning gas, rather than using electricity as the main source of energy to produce chilled water. Typical refrigerant (absorbent) used is Lithium Bromide (LiBr).

The efficiency of a chiller is measured in terms of its coefficient of performance (COP) or energy efficiency ratio (EER), both parameters referring to the efficiency at full load conditions. Since chillers mostly operate at part load conditions, the integrated part load value (IPLV) gives a more representative indication of chiller efficiency across typical loading factors encountered in office type buildings. Water cooled chillers which use cooling towers are more energy efficient than air cooled chillers and they last longer, however, the costs associated with water and water treatment need to be factored in.

Modern chillers have high COPs compared to older chillers, values of 6.5 to 7 are achievable now, compared to 3.5 to 4 thirty years ago. The efficiency of a chiller depends on the technology used in the chiller – for instance variable speed chillers and those that use electromagnetic bearings have made a major impact on improving chiller efficiency. Another factor to consider is part load performance. A large chiller operating after-hours simply to serve a small load such as a lift motor room or a computer room is likely to perform very inefficiently.

Absorption chillers have low COPs when compared to vapour compression types, however, their major energy consumption is gas instead of electricity. This often gives benefits through reducing the carbon footprint of a building and reducing maximum demand charges for electricity. Absorption chillers can also operate using a 'free energy' source such as the waste heat from a gas fired engine or generator set that produces electricity.

Older chillers use CFCs which are refrigerants that are banned from being manufactured or imported by the Montreal Protocol and some others use HCFCs which are refrigerants being phased out. Therefore, Facilities Managers may face the possibility of having to replace older chillers as existing stocks of CFCs and HCFCs diminish and become expensive and/or harder to source.

Another recent option available is the availability of gas engine driven chillers and heat pumps, where an engine powered by gas is used to drive a vapour compression type chiller. These machines have the potential to reduce the carbon footprint of buildings and to reduce demand on the electrical supply.

6.2.1 ENERGY CONSUMPTION AND CHILLER OPTIMISATION

Chillers that operate on the vapour compression cycle mainly use energy in the refrigerant compressor which draws vapour from the chiller evaporator (where heat is extracted and chilled water produced) and compresses this vapour for the purposes of condensing into liquid refrigerant at the condenser (where heat is rejected). The amount of energy consumed by the compressor depends mainly on the efficiency characteristics of the compressor and the pressure difference between the condenser and the evaporator, which in turn is related to condenser temperature and evaporator temperature.

Efficiency characteristics of compressors depend on their type. Centrifugal types of compressor are the most efficient and were only available in large chillers until the advent of the magnetic bearing 'Turbocor' type compressor. Screw type compressors are used in medium size machines. Scroll and rotary types are used in smaller chillers. Reciprocating type compressors were common in HVAC chillers, but are no longer used except for industrial type applications where they are efficient and use refrigerants such as ammonia.

The efficiency of chillers has increased significantly over the past 10–15 years mainly due to advances in compressor technology, improvements to heat exchangers (evaporators and condensers) and better control of compressors using microprocessor technology and advanced control algorithms.

Apart from using electricity at the compressor, air cooled chillers also use electricity for the condenser fans which are incorporated into the chiller. The energy for heat rejection in a water cooled chiller is expended at the cooling tower fans and the condenser water pump. Chilled water pumps also consume energy.

Absorption type chillers mainly use thermal energy to drive the process, with some electricity being used for solution pumps and fans.

To minimise the energy consumption of vapour compression type chillers it is important to operate the chilled water temperature as high as possible and the condenser water temperature as low as possible, both within limits recommended by the manufacturer. This can be achieved in different ways including correct sizing of heat exchangers for energy efficiency during design and through regular cleaning to remove fouling of tubes and plates.

Other means to minimise the energy consumption of a chiller is to increase chilled water and condenser water flow rates and to operate cooling towers (used in water cooled chillers) as close to wet bulb temperature as possible. However, these measures inevitably cause a rise in electricity consumption for other equipment in the system including chilled water pumps, condenser water pumps and cooling tower fans. Therefore, it is important to take a holistic view and make a systems approach when the energy consumption of chilled water systems is optimised, otherwise efficiency gains made at the chiller could be lost elsewhere in the system. It is very important for Design Engineers to carefully evaluate the benefits from higher chiller system efficiency, during the design process.

6.2.2 MAINTENANCE & OPERATION

The following issues are important for the efficient maintenance & operation of chillers:

- Manufacturers' guidelines and advice regarding maintenance must be followed. Refer to AIRAH DA19 and other references for typical maintenance schedules
- Heat exchangers must be maintained in a clean state. Air cooled condensers must be regularly cleaned and kept free from restrictions to air flow from debris such as leaves. Vandalism (fin bashing) and hail damage could also affect the performance of heat exchangers. Water cooled condensers must be cleaned at regular intervals and/or when evidence of fouling is noted through high temperature approach values. It is estimated that a build-up of a 0.6mm thick layer of fouling on the condenser water tubes will reduce chiller efficiency by 20%. For larger chillers, the installation of automatic tube cleaning systems may be cost effective
- It is recommended that performance based maintenance is carried out on chillers, in addition to scheduled replacement of components as stated in manufacturer's instructions. This relies on regular measurements of parameters including temperature and pressure drops through heat exchanges and monitoring of chiller COP. This is ideally carried out on a continuous basis by a BMS, however, where such systems are not available, this may be achieved through regular recording of the data on maintenance log books, by Maintenance Staff
- Older chillers using reciprocating type compressors have thermostatic type expansion valves and replacing these with electronically controlled expansion valves will deliver efficiencies in the order of 15–25%
- The refrigerant charge must be regularly checked and any leaks repaired promptly. Apart from environmental impacts including global warming and ozone depletion, the loss of refrigerant is expensive and will cause a reduction in plant capacity and efficiency
- Regular checks must be carried out for water leaks from chillers and the chilled water distribution system and any leaks rectified promptly, with a re-instatement of water treatment chemicals
- Check pipework insulation on chiller and chilled water pipework and components
- The efficiency of a chiller can be enhanced by increasing the chilled water temperature and/or decreasing the condenser water temperature within certain limits permitted by the chiller manufacturer. Typically a 1ºC rise in chilled water temperature or a 1ºC lowering of condenser water temperature improves chiller efficiency by 2–3%. This method of chiller optimisation is called 'chilled water re-set' or 'condenser water re-set' and this method of chiller optimisation is possible for most buildings when suitable (mild) ambient temperature conditions prevail.

  Note:

  1. Consideration must be given to factors that might negate some of the efficiency gained at the chiller. For instance raising the chilled water temperature will improve the chiller efficiency but more supply air may be required from the air handling units to satisfy the building cooling load, thereby increasing fan energy consumption at the AHUs. Similarly, the extra energy necessary at the cooling tower fans to lower the condenser water temperature might negate the efficiency gains made at the chiller. There are well established smart control strategies (algorithms) which minimise the risk of these 'claw back' effects negating energy efficiency initiatives and the Facilities Manager and Maintenance Contractor should seek expert assistance when considering major upgrades or the implementation of smart controls for chiller optimisation
  2. The chiller manufacturer must be consulted with regards to the maximum permissible evaporating temperature and minimum acceptable condensing water temperature. Certain types of chiller are less tolerant of low condensing water temperatures, e.g. older centrifugal machines, reciprocating chillers that use thermostatic expansion valves and some screw types.

- Optimise the chiller sequencing strategy by operating the most efficient chiller to meet the prevailing cooling load. Inhibit chiller operation (by chiller lock – out) during low ambient temperatures when there is no demand for chillers to operate and ensure that spurious cooling calls are minimised
- Ensure chiller control temperature sensors are calibrated and read true, inaccurate readings will lead to inefficiencies or loss of capacity
- Where large chillers, their associated pumps and other equipment such as cooling towers are being

used to serve small after-hours loads such as lift motor rooms, security control rooms and server rooms, consider the installation of dedicated supplementary HVAC systems to serve these areas after-hours rather than wastefully using central chiller plant.

6.2.3 REPLACING & UPGRADING

The following points are given as indicators to consider chiller replacement and/or upgrade:

- The chiller has refrigerants which have been phased out or are due to be phased out soon, refer to 'Further Information' given at the end of this section
- Chiller is more than 15 years old and spare parts are getting hard to source
- Chiller is proving to be unreliable or is due for a major (expensive) overhaul
- The cooling demand from the building has increased significantly
- The after-hours load of the building is such that the chillers operate very in-efficiently.

If a chiller needs to be replaced, various factors must be considered. Simply replacing a chiller with a new machine sized for the same duty will result in lost opportunities for saving energy. Seek specialist advice and consider the following factors:

- Select chillers with high COPs and IPLVs which are better than current BCA Section J requirements
- Optimise chiller selection, don't simply replace with the same capacity as the existing. The building cooling load may have changed over the years. Consider the demand cycle of the entire chiller system and optimise the new chiller after investigating what its duty cycle would be. Seek advice if necessary, the potential financial and operational benefits from optimised chiller selection are significant
- Select a chiller that would be compatible with modern control strategies for saving energy and check that the chiller controls have the necessary communication interfaces such as BACnet, Modbus or LON. Factors to consider are chilled water re-set, condenser water re-set, chiller load limiting capability and variable chilled water flow
- Optimise the chiller sequencing and controls strategy to operate the most efficient chiller to meet the prevailing cooling load. Implement energy smart strategies such as chilled water and condenser water reset
- Install equipment for monitoring chiller operation and efficiency. This information may be readily available through the chiller controller or it may be necessary to install additional metering such as kWh, thermal energy metering or some additional temperature sensors connected to the BMS
- Consider implementing variable pumping of chilled water, to save energy. This measure is likely to be effective where the chilled water has to be pumped over long distances or where there is significant throttling of the primary chilled water flow.

6.2.4 REFRIGERANT HANDLING IN HVAC SYSTEMS

The emission of all refrigerants from chillers and other HVAC equipment including packaged and split type systems must be avoided. Apart from potential environmental harm from certain refrigerants and the direct costs associated with replacement of refrigerant, indirect costs are incurred through lower efficiency of the equipment and possible impacts on NGERS reporting to a large facility.

It is illegal for refrigerants that have global warming or ozone depletion potential, to be vented to the atmosphere. It is irresponsible for persons including Maintenance Staff and Facilities Managers not to make best endeavours to identify and promptly rectify any refrigerant leaks. It is a legal requirement for tradesmen working on refrigeration plant including chillers and air conditioning equipment to be appropriately licensed. The Australian Refrigeration Council Ltd. (ARC) is the body that manages the regulations under the *Ozone Protection and Synthetic Greenhouse Gas Management Act (1989)* and the ARC provides the HVAC industry with information and guidance to comply with the law.

For systems where refrigerants are in use, measures must be taken to ensure that all maintenance activities including handling, storage and retrofitting of refrigerant are carried out in accordance with good practice, and this must be stipulated in contract conditions. For larger facilities the inclusion of a KPI that monitors the amount of refrigerant usage is essential. Refrigerant leakage monitoring systems are increasingly being specified together with liquid receivers large enough to store the system charge. For all facilities, maintenance log books must record the amount of refrigerant added to systems and Maintenance Staff must bring to the attention of the Facilities Manager any abnormal consumption.

With good chiller design, refrigerant management and chiller maintenance, annual leakage can be reduced to around 1.5–2% of the refrigerant charge.

Further Information

1. HB40.1, The Australian Refrigeration and Air-conditioning Code of Good Practice – Reduction of emissions of fluorocarbon refrigerants in commercial and industrial refrigeration and air-conditioning applications ISBN: 0-7337-4170-3
2. Australia and New Zealand Refrigerant Handling COP 2007 – DEWHA: ISBN 978 0 642 55379 3
3. The Australian Refrigeration Council Ltd. Website www.arctick.org
4. Refrigerants Australia. Website www.refrigerantsaustralia.org.

6.3 Cooling Towers

Cooling towers are used for the rejection of heat from water cooled chillers. Cooling towers draw heat rejection water (referred to as condenser water) from the chiller and this water is sprayed as droplets through a stream of outside air drawn by a fan, thereby evaporating a small proportion of the condenser water and cooling the remainder in the process. The ambient air drawn through the cooling tower increases in humidity and temperature, and is discharged to the outside atmosphere.

A chiller is more efficient (performs with a higher COP) when it uses a cooling tower for heat rejection, rather than an air cooled condenser because the condensing temperature of the chiller can be lower due to the effects of evaporation of water. Water cooled chillers also last longer than air cooled chillers. A cooling tower can reduce the condenser water temperature down to typically 4–5ºC above the prevailing ambient wet bulb temperature. The difference in temperature between the water leaving the cooling tower and the ambient wet bulb temperature is referred to as the *cooling tower approach*. The difference between water entering temperature and water leaving temperature is known as the *cooling tower range*.

Systems that use cooling towers suffer the penalty of costs for water consumption and water treatment to minimise risks from Legionella. Due to the costs associated with water treatment, the use of cooling towers is not cost effective for small chillers, typically below 600–800kW capacity, unless they are part of a larger multi-chiller installation. The presence of a cooling tower in a building can significantly lower the energy consumption for air conditioning but significantly increase the water consumption. Where installed, cooling towers typically account for 30–40% of the total water consumption of a building.

A recent development is the use of adiabatic type coolers which only consume water for evaporative cooling during conditions of high ambient temperature. Adiabatic coolers operate using the cooling effect from the evaporation of water to pre-cool ambient air that is passed across heat exchangers. When used in suitable (dry) geographic regions, these have the potential to deliver energy efficiency and low water consumption, without the associated water treatment costs for the prevention of Legionella. An adiabatic cooler has a smaller water content than a cooling tower, therefore, it is not classed as requiring mandatory water treatment.

6.3.1 WATER CONSUMPTION

Water is lost from a cooling tower mainly due to evaporation, which is necessary for the tower to function. Water is also lost through 'drift and splash' which is the inevitable loss of water droplets to the air stream and the surrounding area. A cooling tower also loses water through 'bleed' which is the intentional discharge of water in order to reduce the concentration of solids (minerals and organic matter) in the water. Bleed is typically controlled by an automatic system which senses 'Total Dissolved Solids' (TDS) in the water within the cooling tower. The ratio between the TDS in the cooling tower/TDS in the mains water supply is referred to as the 'cycle of concentration'.

In a well maintained tower the ratio of water consumption is as follows:

Evaporation (88%): Drift and Splash (7%): Bleed: (5%).

6.3.2 ENERGY CONSUMPTION

Cooling towers use energy at the tower fans. The use of high efficiency fans and motors together with VSDs will reduce energy consumption. As described in the previous section for Chillers, it is important to use control strategies that optimise the energy consumption of cooling towers and the chillers they serve, rather than considering the cooling tower only.

6.3.3 MAINTENANCE & OPERATION

The following issues are important for the efficient maintenance & operation of cooling towers.

- Manufacturers' guidelines and advice on maintenance specifications must be followed. Also refer to AIRAH DA 19 and AIRAH DA17
- Ensure that there is no overflow of water from the cooling tower basin due to:
  - Faulty water level controls
  - The volume of water within the high level return line draining to the sump, when the tower stops operating

- Where multiple towers are installed, a lack of a balance pipe to equalise water levels.

- Water leaks from pipes and faulty valves must be eliminated
- Optimise the water bleed rate in accordance with the quality of the mains water, the water treatment regime and the type of cooling tower. Where automatic TDS controls are installed, they must be calibrated and adjusted correctly. Where such controls do not exist, their installation will be beneficial because excessive water bleed is wasteful and insufficient bleed will lead to corrosion and/or scaling of heat exchangers. Operating cooling towers with cycles of concentration typically below 3–4, indicates water wastage, operating typically above 6–7 produces little gains in water efficiency, with increased risks of corrosion and other water quality problems
- The type and condition of splash guards and drift eliminators must be checked to ensure that water wastage due to poor design and/or condition of the splash guards and drift eliminators is minimised. Replacement drift eliminators must comply with AS 4180 which limits the drift loss to 0.002% of the maximum design water circulation rate through the cooling tower. Aggressive action from water treatment chemicals and exposure to the sun will degrade these components over time
- The cooling tower fill must not be allowed to gather excessive fouling and regular inspection in accordance with AS 3666 should be carried out. Apart from the microbial hazards, excessive fouling on the fill material could also affect the breakdown of water flow and make the cooling tower less efficient by increasing the temperature approach of the tower
- The airflow around cooling towers must not be restricted. Discharge air from cooling towers must not be allowed to re-cycle into the intake. If prevailing winds are affecting the air flow through a cooling tower, it may be necessary to construct a wind barrier
- Where a cooling tower bypass valve is installed, there must be no conflict of controls between the valve being open and the fans being operated. Ensure that there is at least a 2ºC differential between the valve closing and the cooling tower fans operating
- The strategy for staging cooling towers and their fans must be optimised. Best efficiencies will be gained when all available cooling towers are operated in parallel, rather than running the lead cooling tower to maximum and staging the remainder. To obtain the best efficiency, fans should be speed controlled through VSDs, rather than being switched on/off or two speed operation. As the demand for heat rejection increases from the chillers, initially each fan should be operated at the minimum permissible speed. Once all fans have been enabled, they should be modulated in unison
- Control algorithms must be programmed to minimise fan power consumed, to deliver the desired condenser water temperature to the chiller. Often, the set point for control of cooling tower fans is below the prevailing ambient wet bulb temperature and this wastes energy because the fans are being driven to operate at 100%, attempting to deliver the impossible. This energy wastage can be minimised by controlling the cooling tower fans to deliver condensing water temperatures which track the prevailing ambient wet bulb temperature by 3–4ºC, depending on the capability of the tower. The control strategies for optimising chiller efficiency and cooling tower efficiency must be coordinated, to ensure that the benefits from one don't negate the other
- If a plate heat exchanger (PHE) is installed to protect equipment such as supplementary HVAC units connected to an open circuit cooling tower, ensure that the pressure drop through the PHE is not excessive and that the system is not fouled. If the pressure drop is excessive, typically >30kPa, then consider the addition of more plates to the PHE and re-balancing the water flow rate. Pumping energy can be saved by the installation of two port motorised valves at the supplementary air conditioning units. These valves should shut down water flow to the supplementary units when the refrigerant compressor is not in operation, thereby enabling the Tenants condenser water pump to be slowed down through VSD control. Ideally this measure should be implemented at design stage, or when supplementary HVAC units are replaced. If this measure is being retrofitted, to avoid issues with nuisance tripping of compressors, it is important that systems are specified to incorporate the necessary time delays and control interlocks that ensure adequate water flow through the units when the compressor is in operation. It is important for this issue to be covered in 'tenancy fit-out guidelines' to ensure that supplementary HVAC units installed by the Building Occupants incorporate such features that save energy consumption of base building systems

- It is essential for energy efficiency and water conservation that monitoring of cooling tower performance is carried out, including the following:
    - Water consumption by installing dedicated water meters, preferably connected to the BMS. Alarms must be set up to register if water is consumed after-hours or exceeds pre-determined quantities
    - For larger installations, the monitoring of cooling tower fan energy consumption, together with performance indicators such as ambient wet bulb, condenser water flow temperature and VSD speed
    - Total dissolved solids (TDS) sensors, independent from the TDS control sensor with alarms set to register if TDS value is too high – typically 1,500ppm max (which indicates insufficient bleed – risk of corrosion and/or fouling the heat exchangers) or too low – typically below 1,000ppm (which indicates water wastage). Seek the advice of a water treatment specialist for site specific advice.

6.3.4 REPLACING & UPGRADING

Consider the following issues before cooling towers are replaced or upgraded:

- Replace with new fill material that has degraded and drift eliminators that comply with AS 4180
- Consider the cost benefits of replacing cooling towers with adiabatic type coolers which work well in dry climates. The capital cost of these units will be higher and they will require a larger footprint and the overall energy efficiency of the chilled water system will be lower. However, life cycle costs could be lower due to reduced water consumption and the elimination of water treatment costs associated with the prevention of Legionella. For certain applications where the risks associated with Legionella must be eliminated, this type of system will give a definite advantage
- The use of re-cycled water for cooling towers may be feasible and initially this must be discussed with a water treatment specialist. Using re-cycled rain water and condensate collected from the drains of HVAC air handling units may be cost effective for saving costs associated with water treatment, because re-cycled water is likely to contain less dissolved solids than mains water.

Further Information

1. AIRAH DA 17 – Cooling Towers: ISBN 978 0 949436 46 7
2. Sydney Water: Best Practice Guidelines for Cooling Towers in Commercial Buildings. www.sydneywater.com.au
3. Water Efficiency Guide – Department of the Environment and Heritage: ISBN 06425 52878.

6.4 Air Handling Units & VAV Boxes

6.4.1 AIR HANDLING UNITS

Air handling units (AHUs) are used to condition and circulate air within buildings. AHUs typically contain air filters, a circulating fan, cooling coils and heating coils. The cooling coils have chilled water supplied from the chillers and the heating coils have heating hot water supplied from heat generators, typically referred to as boilers. Some AHUs have electric heating elements to provide space heating. Sometimes AHUs also have humidifiers installed (for increasing the humidity), although the use of these are rare in office type buildings due to a relatively wide band of tolerance to conditions of low humidity.

Depending on the type of HVAC system, AHUs may either be constant air volume or variable air volume (VAV).

AHUs supply a mixture of outside air and recirculated air to the occupied space, this mixing of air being carried out by modulating dampers within a mixing plenum. During early morning 'warm up' or 'cool down' cycles, the outside air dampers should be set at 0% to minimise energy consumption. When suitable outside conditions prevail (mild temperature and low humidity), the amount of outside air can be increased to 100%, thereby reducing chiller operation and saving energy. This process is called the 'economy cycle'. Operating AHUs overnight and using low temperature ambient air to pre-cool buildings is called 'night purge'. For certain types of building which have high thermal mass, night purge can be an effective means of reducing daytime chiller operation and energy consumption. However, the controls strategy must ensure that heating systems do not operate spuriously after night purge and the overnight fan energy consumption does not exceed the benefits from overnight cooling.

Poor control of airflow and temperature are a common cause for low efficiency in AHUs. Optimisation of the performance of an air distribution system depends on the proper interaction (coordination) between the AHU controls and the controls within occupied areas (zones) such as VAV terminal devices.

6.4.2 VAV BOXES

VAV boxes (also known as VAV terminals) are devices that control the supply air flow into zones within occupied spaces. Each VAV box receives supply air from an AHU and a box typically serves a number of supply air diffusers located within a zone in the occupied space. The Design Engineer has an influence on the zoning of occupied spaces, location of the VAV boxes, the type of supply air diffusers and factors such as the minimum and maximum air supply flow rates. *The Property Council of Australia – A Guide to Office Building Quality* (www.propertyoz.com.au/) gives guidelines on the maximum size of zone to be served by one VAV box. Smaller zone sizes reduce temperature variations within the zone thereby enhancing comfort but increasing capital cost. During office fit-outs, the design parameters for a zone are sometimes changed and factors such as higher occupant densities, higher equipment loads, the installation of partitions and the location of office equipment in a manner that affects temperature sensors all contribute to non-performance of VAV boxes resulting in discomfort and/or energy wastage.

Each VAV box is controlled by a temperature sensor, the supply air volume being reduced as the zone temperature reaches set point, a minimum supply air rate being maintained for ventilation purposes. Often VAV boxes are installed with re-heat capability, being either electric or hot water. Reheat is required either for heating perimeter zones and/or to maintain comfort conditions within the zones. Sometimes, even with the supply air flow to a zone throttled down to minimum, the cooling effect of the supply air is sufficient to cause over cooling to the zone, thereby the VAV box having to use re-heat to maintain comfort conditions. Minimisation of re-heat is essential towards making VAV systems efficient.

Modern VAV boxes are 'pressure independent' type and they can maintain the design air flow rates in spite of supply air pressure variations. Some VAV boxes, typically found in older buildings are fan assisted – the 'series fan' type has a fan which operates continuously, the 'parallel fan' type has a fan that is operated when extra air flow is required for purposes such as space heating. Parallel fans can also be switched independently of the main AHU for morning warm up of perimeter zones.

Poor setting up of design maximum and minimum air flows in VAV boxes, poor control strategies including a lack of coordination between VAV boxes and the AHU that serves them, broken VAV boxes and leaking hot water valves are collectively responsible for significant amounts of energy wastage in typical offices that are served by VAV systems. These problems often remain unnoticed because the heating system counteracts the cooling system, therefore, comfort conditions are maintained and service call outs are not initiated. Energy wastage is increased when zone set points are altered by operators in an attempt to 'quick fix' complaints of discomfort, without investigation of the root causes. Random alteration of zone set points can cause the relevant AHU to over cool the supply air to an extent which creates a significant re-heating demand at other zones and it is not a rare occurrence in buildings for heating boilers to operate in the height of summer, fighting the cooling system and wasting gas and electricity.

6.4.3 ENERGY CONSUMPTION

Energy consumption from AHUs is mainly for fans and for electric heaters where installed. However, AHUs have the potential to significantly affect the energy consumption of major energy consuming plant such as chillers and boilers from issues such as poor economy cycle operation, excessive use of outside air, dirty heat transfer surfaces and poor control of heating and cooling coils, including valve leakage that causes simultaneous heating and cooling.

To minimise fan energy consumption, the issues covered in Section 6.7 are important. Minimising air flow rate in a VAV system is dependent on using a good control strategy to modulate fan speed in response to decreasing demand from VAV terminals. Minimising the resistance to air flow can be achieved through monitoring and periodic cleaning or replacement of air filters. Also important is to ensure proper commissioning which minimises unnecessary throttling, including resistance from excessively long lengths of flexible ducts and squashed ducts. The possible removal of unnecessary restrictions such as noise attenuators also needs to be assessed using an acoustic consultant if necessary.

Excessive or unnecessary Humidification and Dehumidification will also waste energy and this topic is addressed in Section 6.8.

6.4.4 MAINTENANCE & OPERATION

The following issues are important for the efficient maintenance & operation of AHUs:

- Ensure heat exchange coils are kept clean. Dirty heat exchange surfaces increase resistance to heat transfer, thereby reducing chiller and boiler efficiency. Dirty coils also increase the resistance to air flow, the consequences of which are either an increase in fan energy consumption (where VSDs are installed) or a reduction in airflow with possible discomfort and inadequate ventilation. The AIRAH best practice guideline 'HVAC Hygiene' covers the assessment of cleanliness within ductwork systems

- Replace or clean air filters regularly, in accordance with the maintenance schedules. Dirty air filters lead to an increased resistance to air flow and compound the effects mentioned above. Filter differential pressure gauges installed across the air filter banks are essential to assess the cleanliness of filters
- Some air filter chambers are fitted with blanking plates and don't maximise the filter area. Replacing the blanking plates with air filters will reduce fan static pressure, thereby reducing energy consumption. An added benefit will be an increase in the filter changing interval
- Assess whether the efficiency of the installed air filters is appropriate for the application. If the air filters are too restrictive i.e. more efficient than what is required, the pressure drop across the filter will be excessive and fan energy consumption will be high. For typical office type buildings if a filter class in excess of F5 is installed, the reason for this needs to be investigated and where possible, air filters that have a lower pressure drop should be substituted
- Assess whether duct mounted noise attenuators are necessary and remove these where possible. The original Design Engineer may have been over cautious with acoustic design and attenuators cause resistance to air flow which leads to energy wastage. Engage the services of an Acoustic Consultant where necessary
- Check for leaking heating and cooling control valves, which have the potential to cause the heating system to fight the cooling system. This is a common problem in buildings that is often unnoticed and wastes a lot of energy
- Regularly inspect and eliminate all sources of air leakage through damaged flexible connections, poor ductwork joints and access doors/panels
- Ensure that the economy cycle is set up correctly and it functions satisfactorily. Common causes for in-efficiency include incorrect control algorithms, failed dampers/control actuators and failed temperature / humidity sensors. The incorrect operation of the economy cycle is one of the most common causes of energy wastage in buildings
- Avoid the installation of motors which have poor efficiency – especially re-wound motors on large AHUs. The life cycle energy cost of an electric motor is significantly higher than its capital cost
- Ensure that branch dampers are installed and are in operation to minimise wasteful after-hours air conditioning and the air conditioning of vacant zones
- Check belt tension and rectify any misalignment between belts and pulleys, thereby minimising losses due to friction. For large motors, typically greater than 20kW and where VSDs are installed, investigate the feasibility of installing positive drive belts and toothed pulleys rather than V type belts, to reduce frictional losses
- Investigate whether AHUs are performing active de-humidification or humidification, in order to maintain close control of humidity – a feature which is not essential in typical office type buildings. Seek specialist advice and either disable these functions or operate the systems over a wide dead-band to reduce de-humidification and humidification
- Buildings that have chilled beams will require active dehumidification of outside air under certain circumstances. Investigate the control set points for safety margins which are excessively conservative and check the calibration of the dew point sensors
- On constant air volume type AHUs, check whether the fan is oversized and whether there is excessive throttling of airflow from dampers. The preferred solution is to re-size the pulley ratio and to open the dampers to reduce throttling
- Ensure that service lights inside AHUs are not left continuously in operation. Light switches should have indicator lamps and Maintenance Staff must be advised to switch these lights off and the Facilities Manager should carry out random inspections to ensure compliance
- Check the accuracy and location of zone temperature sensors. Common issues that affect energy consumption are poor sensor calibration, air leakage into the sensor through poor gland sealing and sensors being affected by heat sources such as sunlight and office equipment such as computers. These issues can drive the zone AHU to supply excessive cooling, heating or air flow, thereby wasting energy. Tenancy fit-out guidelines should address the issue of Tenant's equipment adversely affecting control sensors
- Control fan coils using room air temperature sensors, rather than return air sensors

- Ensure that alterations carried out during tenancy fit-outs do not affect airflows into the zones. Wall partitioning that disrupts air flow, excessive lengths of flexible ducting, squashed flexible ducting and disconnected supply air diffusers sometimes with supply air ducts that are open ended, are common causes for zone temperature control failure that drive AHUs to perform inefficiently
- On VAV systems, implement and monitor the following, utilising trending functions of the BMS where possible:
  - The pressure control set point for the AHU supply air fan being set too high or the sensor being faulty and the fan operating at constant speed without modulating, thereby wasting energy
  - The correct location of the pressure sensor is also important, typically this is installed 2/3 of the distance into the index run
  - The AHU fan is controlled to a critical zone re-set algorithm which minimises duct static pressure. This can be achieved by dynamically resetting the duct static pressure to maintain at least some VAV boxes fully opened
  - Variable pitch inlet guide vane mechanisms are operating correctly
  - Supply air temperature being set too high (wastes fan energy). Supply air temperature being too low (wastes energy for re-heating)
  - The operation of VAV boxes. Often there is at least one faulty VAV box on each floor or in each zone. Apart from the discomfort and wasted energy at this zone, if the control algorithm is set to drive the AHU based on the parameters sensed at the worst performing terminal, this could lead to high energy wastage due to excessive cooling and wasteful reheating at the other VAV boxes. Regular monitoring of VAV boxes enables prompt repairs and setting up smart control strategies will help to reduce energy wastage. Also, control algorithms should drive the AHU fan based on a high percentile (of VAV boxes) basis, to avoid a faulty VAV box influencing its operation excessively.
- If monitoring indicates issues which are due to a lack of air balancing, then it will be advisable for systems to be re-balanced and re-commissioned, at least on a floor by floor basis. Quite often Facilities Managers do not prioritise this important issue due to a lack of understanding of the problems, shortage of funds and a lack of appreciation of the potential benefits. If a Maintenance Contractor can effectively target the system deficiencies through monitoring the BMS and make an effective business case for re-commissioning, then this work is more likely to gain approval to proceed, with benefits in efficiency and improved comfort
- Check the minimum and maximum air flow settings on the VAV terminals. These are initially determined by the Design Engineer, in accordance with assumptions made at design stage. However, until the Building Occupants move in and the thermal characteristics of the building are actually established, there is no possibility to confirm whether these values are optimal. If the minimum air-flow setting at a terminal is too high, there could be wasteful re-heating at the terminal, and during shoulder seasons, this could trigger a heating call that operates the entire heating system, thereby wasting significant amounts of energy. If the maximum airflow is too low, this could drive-down the supply air temperature of the AHU in order to satisfy the cooling demand of this zone, and this in turn could cause wasteful re-heating at other terminals. Often, Design Engineers are conservative with the specification of the minimum air flow rate setting (the minimum setting is specified high), due to concerns with discomfort due to 'dumping' of cold air and compliance requirements of AS1668.2 with regards to minimum outside air requirements. Providing the minimum outside air requirements for the occupancy is satisfied, it is often possible to adjust the minimum air flow rates to as low as 30% of design for swirl type diffusers, without causing discomfort from 'dumping' of cold air
- Using the BMS to monitor VAV boxes and the sources of heating and cooling calls will enable potential issues that cause inefficiency to be identified. It may be necessary to engage the services of a Controls Specialist to set up the necessary smart control algorithms to avoid such issues
- Many buildings do not have the design air and water flows in operation. Common reasons for this include the HVAC Systems never being commissioned and balanced initially or over the years, or office fit-outs have been carried out with no regard to air balance issues. Sometimes, office fit-outs change the zone heating and cooling loads which have a bearing on the required air flow rates. The importance of proper commissioning, fine tuning, re-balancing and

retro-commissioning is now well accepted. Often, the costs (and logistics) associated with fully retro-commissioning a building prevents Facilities Managers from addressing this important issue. Therefore, it may be more cost effective and feasible for air and water balancing to be carried out during the tenure of a maintenance contract, at least on a staged basis, e.g., on a floor by floor basis.

6.4.5 REPLACING & UPGRADING

Consider the following issues before AHUs are replaced or upgraded:

- Avoid simply replacing like with like. Ensure that the design air flow rates are re-assessed, with consideration of factors including design heat losses and heat gains, which are likely to have changed since the original design of the building. Possible reasons for this include the construction of new buildings nearby that provide shade and the installation of energy efficient lighting. Consider whether the design supply air temperatures are appropriate for energy efficiency, investigate potential benefits from a lower supply air temperature – lower air volume flow rates and lower fan energy verses higher chiller energy consumption
- Ensure that fan and motor efficiencies are at least up to BCA and MEPS requirements
- Consider maximum use of the economy cycle, control of outside air based on CO_2 concentration in the occupied areas and the installation of heat exchange between the supply and exhaust air streams
- Carefully select the supply air fan for efficient operation. Install high efficiency motors and low loss belts and pulleys including toothed belts. The use of plug type fans (which don't have belt and pulley losses) may be beneficial
- Do not re-wind motors, unless there is a guarantee of the efficiency. Higher energy costs of a re-wound motor are likely to outweigh savings in capital cost. It is recommended that a purchasing strategy is in place and Maintenance Contractors are instructed accordingly, to ensure that replacement fans and motors are energy efficient. Replacement of existing fans also presents good opportunities to remedy existing problems such as throttling of air flows, which leads to energy wastage
- If the air supply diffusers are to be replaced as part of a major fit-out, consider high efficiency swirl type diffusers which have high turn down ratios, which will reduce re-heat requirements significantly and reduce energy wastage
- Install duct static pressure sensors at appropriate locations, ensure efficient control strategies such as critical zone re-set are in place to minimise fan energy consumption
- During fit-outs, duct pressure sensors that Control VAV fan operation can sometimes be displaced, or installed in an incorrect zone. This must be avoided
- Before operating new AHUs, ensure that ductwork is cleaned to prevent new air filters being rendered dirty.

6.5 Boilers

Gas fired boilers are commonly used in buildings to provide heating hot water for the air handling units. The term 'boiler' is the traditional name given, however, the term 'hot water generator' is more representative. Most commercial buildings have boilers producing heating hot water at temperatures below 85ºC and are referred to as low temperature hot water (LTHW) or low pressure hot water (LPHW) boilers.

Boilers can be grouped according to whether they are naturally aspirated (atmospheric) or forced draught, the latter type being more efficient and compact. Modern boilers are much more efficient than older boilers due to technological advances including the use of pre-mix type burners, accurate controls, high efficiency fabricated type heat exchangers and good thermal insulation.

Condensing boilers are very efficient, with thermal efficiencies typically exceeding 96% – based on the gross calorific value. These boilers extract a very high percentage of energy from the combustion products thereby 'condensing' the flue gases – often evident through a visible plume of vapour in the exhaust. Condensing boilers have been successfully used in European countries for the past 20 years and their installation is mandatory in some countries. For condensing boilers to be optimally efficient, the return water temperature to the boiler has to be below 55ºC, an important factor to consider when retrofitting these boilers. This should ideally be achieved by appropriate sizing (over-sizing) of the heat exchangers or by specially designing the heating circuits to ensure that some 'cool' water returns to the boiler. However, these options are sometimes not available when retrofitting condensing boilers under maintenance contracts. Efficiency gains are also possible by scheduling the heating water temperature to be high only during the relatively short periods for initial warm up and during extremely cold weather, the remainder of the time the water temperature being low enough to cause condensing conditions. If condensing and conventional boilers are used in the same heating circuit, it is necessary to consider the effects that low water temperature would have on the conventional boilers, to prevent possible damage due to 'back end corrosion' a term which describes corrosion that occurs in a conventional (non- condensing type) boiler, when the return water temperature falls below 55ºC for prolonged periods.

The efficiency of a boiler depends very much on the cleanliness of its heat exchangers and the state of tuning of the air/fuel ratio at the burner. To obtain optimal efficiency, heat exchangers must be cleaned periodically, combustion analysis must be carried out at least once a year and the air/fuel ratio adjusted for optimal efficiency.

6.5.1 ENERGY CONSUMPTION

Boilers consume fuel, typically gas, in order to heat the water circulating through them. A relatively small proportion of energy is consumed as electricity by components such as burner fans. The efficiency of a boiler depends largely on its type – whether it is atmospheric (least efficient type) forced draught or condensing type (most efficient). In order to maximise the efficiency, the heat losses through the boiler casing is minimised through high efficiency insulation and heat losses from flue gases is minimised by having large heat exchange surfaces. Correct selection and good control through modulation and sequencing of boilers to ensure that the most efficient boilers are operated to meet the load requirements is essential to reduce energy consumption. Also important is regular maintenance to keep heat exchangers clean and tuning of the air/fuel ratio in order to achieve optimum combustion efficiency.

6.5.2 MAINTENANCE & OPERATION

The following issues are important for the efficient maintenance & operation of boilers:

- Manufacturers' guidelines and advice on maintenance specifications must be followed. AIRAH DA19 provides typical maintenance schedules
- Periodically (at least once a year) ensure that the boiler is serviced by a competent service technician who has access to manufacturers data and specialist equipment such as combustion analysis equipment. Servicing should include cleaning of heat exchangers, carrying out combustion analysis and tuning of the air/fuel ratio to optimise combustion efficiency for the range of heat output that the boiler is most likely to operate under, which often is less than 100%
- Ensure water treatment (corrosion inhibition and scale prevention) is satisfactory and water leaks from the heating system are eliminated. Make up water introduces oxygen and dissolved solids into the heating system which could lead to corrosion and/or scaling of heat exchanges and a loss of efficiency
- Check for water leaks from boilers and the heating water distribution system and rectify leaks promptly
- Check for damaged thermal insulation in the heating water distribution system and repair where necessary. For system components such as heat exchangers, valves, strainers and flanges, it is unlikely that retrofitting proprietary thermal insulation to a high standard (that looks good) will be cost effective. However, the installation of 50mm silver foil lined glass wool, held in place with steel mesh and wire strapping will perform as well and cost much less metal cladding
- Poor boiler controls will contribute significantly to inefficiency. Spurious heating calls can lead to high heat losses due to short cycling, standby and pre-purge losses. Ensure that secondary means of control are in place to minimise these issues – e.g. measures such as outside temperature lockouts are recommended
- Boiler sequencing controls should ensure that the most efficient boiler is operated to deliver the load demand. The hot water flow temperature should be minimised to improve boiler efficiency (especially on condensing boilers) and to reduce heat losses from pipe-work. Note: for conventional boilers, to prevent internal corrosion (back end corrosion), ensure that the return water temperature is above the acid dew point (typically 55°C), which is the temperature at which the flue products condense
- Where multiple boilers are installed, especially large atmospheric types (which have high heat losses in standby mode due to natural convection), ensure that water does not flow through boilers that are not in operation. This may be achieved through the manual shut down of boilers (with due consideration given to redundancy), through the installation of motorised valves or the installation of motorised flue dampers.

6.5.3 REPLACING & UPGRADING

Consider the following issues before boilers are replaced or upgraded:

- Do not replace like with like without assessing the heat load of the building and selecting boilers that would deliver a good match between system demand and boiler capacity
- Ensure that boiler efficiency is at least up to current BCA standards
- Consider the installation of high efficiency boilers including condensing boilers – at least as the lead boiler
- For systems that have high distribution pressure losses (typically on systems that have very long distribution runs), consider converting the heating system into a primary/secondary type, in order to reduce pumping energy
- Install gas sub-metering to enable boiler efficiency to be monitored.

6.6 Pumps

Pumps are used in HVAC systems, mainly for the circulation of water, which is used as a medium for heat transfer between chillers, boilers, air handling units and other heat exchangers. The correct selection of a pump and its drive motor is important for energy efficiency. BCA Section J stipulates the maximum permitted power consumption for a particular duty, for new installations. It is accepted that under typical maintenance contracts, replacement of pumps may often have to be carried out on a like for like basis to expedite the re-instatement of an important function. However, it is important for energy efficiency to be considered at the time of replacement whenever possible, especially when replacing large pumps. A purchasing policy set up by the Facilities Manager, which formally considers this aspect will help to focus attention to this aspect.

Apart from their impact on energy consumption, pumps also have the potential to affect water (and energy) consumption if they leak. Commonly used types of pump have gland-type seals and these are potential sources of water leakage. Regular inspections are required to ensure that water leaks are repaired promptly.

6.6.1 ENERGY CONSUMPTION

Pumps consume energy to cause water to flow against the resistance of the system which includes pipework, heat exchangers, valves, strainers and other components. The efficiency of a pump depends on its type and characteristics designed by the manufacturer including manufacturing tolerances. For most HVAC applications centrifugal type pumps are used. To reduce pump energy consumption, it is important to minimise water flow and system pressure drop (resistance to water flow), and to ensure that the pump is selected to operate within a band where its efficiency is high. The efficiency of the motor that drives the pump and the efficiency of the drive system (where indirect drives such as belts and pulleys are used) are also important.

The relationship between the power consumption of a pump, water flow rate and pressure is:

$P = (V \times \Delta P)/\eta$

P = power (Watts).

V= water volume flow rate (m^3/s).

ΔP = pump total (static + dynamic) pressure drop across the pump (Pa).

η = [pump efficiency x motor efficiency x drive (belt and pulleys) efficiency x VSD efficiency].

6.6.2 MAINTENANCE & OPERATION

The following issues are important for the efficient maintenance and operation of pumps:

- Routinely check for water leaks. Refer to AIRAH DA19 for maintenance schedules
- Ensure that all pumps are automatically switched off when the circuits they serve are not in operation
- Regularly check strainers for blockage and clean where necessary. The installation of pressure gauges across strainers and strainer flush valves will assist
- Ensure that there is no unnecessary throttling of system water flow at balancing valves or isolation valves in the index circuit (the circuit which has the highest pressure drop). For constant volume pumping systems, energy savings will be gained by opening the valves on the index circuit and either replacing the impellor (with one smaller), trimming it or the installation of a VSD. The bigger the size of pump is and longer the hours of operation are, the higher the cost benefit of this measure would be
- If chilled water or heating hot water circuits are served by three port valves (i.e. the circuits are constant volume type systems), investigate the feasibility of shutting down the bypass circuit at each valve and effectively operating them as

two port valves, thereby converting the circuit into a variable volume system. Energy will be saved if the pump speed is modulated through a VSD to maintain the design static pressure. The cost effectiveness of this system will depend on the size of system, the operating hours and the extent of tolerance of the chiller or boiler to variable water flows.

Important: Consideration must be given to the minimum water flow rate that has to be maintained through the chiller or boiler that the pump serves. Seek manufacturer's advice regarding this.

6.6.3 REPLACING & UPGRADING

Consider the following issues before pumps are replaced or upgraded:

- Do not replace like for like without first investigating the feasibility of improving energy efficiency through options such as converting constant volume pumping to variable volume pumping systems, seek the assistance from a services Design Engineer where necessary. The installation of motorised valves to the condenser water loop that serves tenant's supplementary HVAC systems is recommended, with the valves shutting off automatically when the unit is not in operation. The Tenants condenser water pump can be controlled through a VSD to reduce its energy consumption
- Ensure that pump and motor efficiencies are at least up to BCA and MEPS requirements
- Ensure that the above issues are covered in tenancy fit-out guidelines. Tenant installed equipment must comply with these requirements and incorporate the necessary control interfaces. It is also important to ensure that the pressure drops through Tenants supplementary HVAC Systems are not excessive, thereby increasing the energy consumption of base building systems
- Avoid re-winding electric motors that fail, the higher energy costs of a re-wound motor is likely to outweigh savings in capital cost. It is recommended that a purchasing strategy is in place and Maintenance Contractors are instructed accordingly, to ensure that replacement pumps and motors are energy efficient. Replacement of existing pumps also present good opportunities to remedy existing problems such as throttling of water flows which lead to higher energy consumption.

6.7 Fans

Fans installed within AHUs are described in Section 6.4. Fans are also installed for the purposes of conveying return air from occupied spaces to AHUs and for purposes of extraction from areas such as toilets and car parks. Specialist fan systems such those installed for fire protection, consume insignificant amounts of energy due to their short hours of operation, hence, are not covered in this document.

The main factors for saving energy from fans include the specification of efficient fans and motors and for new installations, BCA Section J stipulates the maximum permitted power consumption for a particular duty. Ensuring that fans are switched off when not required and reducing the fan speed when possible through the use of VSDs are also important for saving energy. Car park ventilation systems are a good example where significant energy savings can be made through the installation of VSDs which are controlled by Carbon Monoxide (CO) sensors.

6.7.1 ENERGY CONSUMPTION

Fans consume energy to cause air to flow against the resistance of the ductwork system which typically includes heat exchangers, air filters, dampers, noise attenuators and other ductwork components. The efficiency of a fan depends on its type and characteristics designed by the manufacturer. For most HVAC applications centrifugal type fans are used, backward curved centrifugal fans being used in large air handling units. To reduce fan energy consumption, it is important to minimise air flow and system resistance (pressure drop), and to ensure that the fan is selected to operate within a band where its efficiency does not fall. The efficiency of the motor that drives the fan and the efficiency of the drive system are also important. A recent development is the use of plug type fans in AHUs which remove the need for belts and pulleys, therefore, eliminating power transmission losses as well as the maintenance requirement for periodic replacement of belts.

The relationship between the power consumption of a fan, system volume flow rate and pressure is:

$P = (V \times \Delta P)/\eta$

P = power (Watts). V= air volume flow rate (m^3/s).

ΔP = fan total (static + dynamic) pressure drop across the fan (Pa).

η = [fan efficiency x motor efficiency x drive (belt and pulleys) efficiency x VSD efficiency].

6.7.2 MAINTENANCE & OPERATION

The following issues are important for the efficient maintenance & operation of fans:

- Ensure that all fans are automatically switched off when the systems they serve are not in operation
- Ensure that belts and pulleys are correctly tensioned and accurately aligned. Incorrect tension and misalignment increases friction and wastes energy
- Minimise unnecessary throttling of system air flow at balancing dampers in the index circuit (the circuit with the highest pressure drop). For constant air volume systems, opening the dampers on the index and other circuits and either replacing the belts and pulleys to reduce the fan speed, replacing the fan with one that delivers less air flow or the installation of a VSD will deliver energy savings. The longer the hours of operation and larger the size of fan, the higher the cost benefit of this measure would be
- Remove unnecessary restrictions from the system including excessive and/or squashed lengths of flexible ductwork on the index circuits
- Remove noise attenuators from ductwork, where these are not necessary. Engage the services of an acoustic consultant to assess the need for attenuators
- Minimise system volume flow rates. Commissioning and re-balancing of air flows may be necessary to ensure that volume flow rates are within design parameters.

6.7.3 REPLACING & UPGRADING

Consider the following issues before fans are replaced or upgraded:

- Do not replace like for like without first investigating the feasibility of improving energy efficiency through options such as converting constant volume air flow to variable air volume systems, seek the assistance from a services Design Engineer where necessary. The installation of motorised dampers in tenant's supplementary supply air systems and extract systems is recommended, with dampers shutting off automatically when the connected equipment is not in operation. The supply air fan can be controlled through a VSD to reduce energy consumption
- Ensure that fan and motor efficiencies are at least up to BCA and MEPS requirements
- Ensure that the above issues are covered in tenancy fit-out guidelines. Tenant installed equipment must comply with these requirements and incorporate the necessary control interfaces
- Convert car park ventilation systems from constant air volume to variable air volume systems by controlling the fans through VSDs controlled by carbon monoxide (CO) sensors, in accordance with AS1668.2. The cost benefits from this will depend on the size of car park, bigger the area, better the cost benefits
- Avoid re-winding electric motors that fail, the higher energy costs of a re-wound motor is likely to outweigh savings in capital cost. It is recommended that a purchasing strategy is in place and maintenance contractors are instructed accordingly, to ensure that replacement fans and motors are energy efficient. The replacement of existing fans also present good opportunities to remedy existing problems such as throttling of air flows which lead to higher energy consumption
- A recent development is the availability of high efficiency fans that are driven by EC (electronically commutated) motors, which are speed controllable. These should be considered as an option during replacement.

6.8 Humidification & De-Humidification

Humidifiers are used to increase the level of humidity of the air inside buildings, typically under conditions where outside air needs heating during colder (winter) periods. Heating outside air, lowers its relative humidity (RH) and could cause excessively dry conditions inside the occupied spaces. If RH typically falls below 35% for prolonged periods, the occupants could suffer from the effects of runny noses (due to irritation caused to mucus membranes) and static electricity (electric shocks as objects such as office furniture and door knobs are touched). With improved carpet technologies, the latter problem has been resolved to a large extent.

Humidifiers are not typically required in commercial office type buildings when HVAC systems are operated correctly. Problems due to the effects of low humidity are usually caused by the excessive use of outside air, either through over-conservative design or faulty economy cycles. Where humidifiers have been installed, unless due consideration is given to their need and operation, they could be wasting a lot of energy.

Humidifiers used in offices are typically of the electrode boiler type where water is turned into steam using electricity which has a high greenhouse coefficient and also the potential to significantly increase maximum demand charges for electricity. Ultrasonic type of humidifiers are also used, these consume less electricity for the humidification process, but the HVAC system will still require thermal energy (from boilers or electric heaters) to re-heat the supply air, due to the cooling effect of the water evaporated from the ultrasonic humidifier. The use of ultrasonic humidifiers may be advantageous for locations where the cooling effect of air is beneficial such as for summer cooling, however, these units require clean water supplies typically from reverse osmosis (RO) type filters to prevent the formation of dust in the supply air stream, caused by residues from dissolved solids in water.

Active de-humidification is rarely required in office type buildings because occupants can typically tolerate high RH levels of around 60–65% for short periods, providing the prevailing space temperature is low enough to maintain conditions within accepted zones for human comfort. The important exception to this are buildings which use chilled beam technology to provide air conditioning, where a rise in internal space humidity conditions could cause moisture to form (condense) on the chilled beams and to 'rain down' on occupants. Active de-humidification typically cools the supply air below its dew point (thereby condensing the moisture) and then re-heats the air using the space heating system. De-humidification occurs during summer in most air handling units when some condensation of moisture occurs at the cooling coil when heat is removed from the supply air for space cooling.

Facilities Managers and Maintenance Service Providers should be aware of humidification and active de-humidification that are in operation inside buildings.

6.8.1 ENERGY & WATER CONSUMPTION

If steam humidification is used, heat is required to raise the temperature of water to its boiling point and then to change its state from liquid to a vapour, which consumes significant amounts of energy (approximately 2,500 kJ/kg).

Ultrasonic humidifiers and atomising spray type humidifiers inject water into the air stream as an aerosol (minute droplets), which cause the air temperature to drop as the water evaporates by extracting its latent heat of evaporation. This cooling effect could have advantages in summer but in winter, energy must be supplied by other means to raise the temperature of the supply air. Ultrasonic and atomising spray type humidifiers need a clean source of water to prevent dust being generated in the supply air due to mineral residues from the water, the water filtration process also consumes energy.

Apart from the water that is injected into the air stream, steam humidifiers also consume water during purge cycles which periodically flush the humidifier in order to reduce the concentration of total dissolved solids (TDS). If ultrasonic or atomising type humidifiers are used, they may be supplied by reverse osmosis (RO) type water filters which will also consume water for periodic back wash cycles.

Air handling units that have cooling coils for dehumidification use chilled water to cool the supply air below its dew point. This chilled water causes energy to be consumed at the chiller and sometimes the chiller has to work extra hard to cool the temperature of the chilled water below the dew point of air and this affects the efficiency of the chiller. After the moisture is removed, often the air has to be re-heated, which will demand further energy consumption from the heating system boilers or electric heaters.

De-humidification can also be achieved through the use of desiccant type rotors. These systems consume thermal energy to drive moisture out and 're-generate' the rotors, as well as electricity for the fans used to circulate air through the de-humidifier.

6.8.2 MAINTENANCE & OPERATION

The following issues are important for the efficient maintenance & operation of humidifiers and de-humidifiers:

- Carry out an assessment whether humidification and active de-humidification are being used in the building. Assess whether their operation is necessary, giving consideration to any existing service level agreements with the building occupants that stipulate close control of humidity. For typical offices, providing the HVAC systems are designed and operated correctly, there should be no requirement for humidification (or active dehumidification). Where such systems are in use, their removal or restricted operation should be negotiated with the Building Occupants and humidifiers should either be turned off or their operating range restricted. As a minimum, the operation of such equipment should be restricted (held off) during periods of maximum electrical demand, and this measure could make a significant impact to a buildings maximum demand charges for electricity
- Ensure proper calibration of humidity sensors inside the building and the temperature and humidity sensors that operate the economy cycle. If the sensors are inaccurate, this could lead to wastage of energy

- Programme the BMS to make maximum use of the economy cycle, optimising the use of outside air for purposes of space cooling, de-humidification and humidification, as well as for ventilation. This level of programming is not typically found in office buildings, however, with careful setting up of the control algorithms and subsequent fine-tuning, it should be possible to achieve savings
- If the operation of humidifiers and active de-humidification is essential, it is important to monitor their usage, through either the BMS, hours run counters and/or dedicated energy meters
- Where humidification and de-humidification are essential, it is important that the building or the space is well sealed, with leakage of outside air minimised. A typical example being computer rooms which have humidity control, where any gaps in the building fabric will lead to increased operation of the humidifiers.

6.8.3 REPLACING & UPGRADING

Consider the following issues before humidifiers and de-humidifiers are replaced or upgraded:

- Where feasible, design-out humidification and de-humidification systems
- Where such systems are required, minimise their operation by using wide control bands and using the economy cycle as much as possible
- Consider alternative technology such as desiccant dehumidifiers for energy efficiency
- Consider the use of heat (and moisture) exchangers (enthalpy wheels).

6.9 Packaged HVAC Systems

Packaged HVAC Systems, split type AC Systems and AC Systems that reject heat to a common condenser water loop are likely to be installed in most office type buildings. Such systems are typically installed to serve areas such as lift motor rooms which need cooling after the main HVAC plant has shut down, security and other office areas that operate continuously and office areas that have high cooling loads which cannot be serviced by the base building HVAC System. It would be rare to find such HVAC Systems serving large commercial office areas, except perhaps variable refrigerant volume (VRV) type systems being installed to serve offices – instead of chillers, boilers and air handling units.

Tenant's supplementary HVAC Equipment is powered through the Tenant's distribution board, and this equipment is usually maintained by the Tenant. Inefficiencies associated with the operation of such equipment are borne by the Tenant. Base building services can be affected when Tenant installed Supplementary HVAC Systems counteract the central HVAC plant, thereby causing energy wastage. Some supplementary HVAC Systems also depend on central plant for their operation, examples being condenser water and tempered outside air supplied by the base building, and these have an impact on the energy consumption of the base building.

6.9.1 ENERGY CONSUMPTION

Packaged air conditioners use energy mainly for the operation of refrigerant compressors, as explained in Section 6.2 for chillers. Energy is also by evaporator and condenser fans. Some air conditioners have electric heating which also consumes energy.

For compressors to operate efficiently the system must have the correct amount of refrigerant charge and the controls (either thermostatic or electronic expansion valves) must be adjusted correctly to minimise superheat at the exit from the evaporator. It is also essential that heat exchangers are maintained clean and air filters are changed regularly to reduce pressure drop. Some package air conditioners have economy cycles, the failure of which could lead to significant energy wastage.

6.9.2 MAINTENANCE & OPERATION

The following issues are important for the efficient maintenance & operation of packaged HVAC Systems:

- Ensure systems are regularly serviced in accordance with manufacturer's instructions The filters must be replaced, heat exchangers (evaporator and condenser) cleaned and the refrigerant charge checked and topped up where necessary. With modern zeotropic type refrigerants, it may be necessary to replace the entire charge rather than simply topping up. The operation of controls must be checked, including the expansion device and superheat setting. Refer to AIRAH DA19 for typical maintenance schedules
- On VRV systems, maintenance is especially important. These systems are specialist in nature and it is important to ensure that service technicians are trained by the manufacturer and they have the necessary diagnostic software and tools

- The correct operation of the economy cycle where installed
- Where an economy cycle is not installed, consider the installation of such a system, this would typically be cost effective for large systems except in the northern regions
- Minimising the operation of individual units, based on time and temperature controls. Investigate whether it is necessary to maintain areas such as lift motor rooms at 20°C (as is common), when a temperature of 27°C (or possibly higher) is sufficient to keep lift maintenance technicians comfortable during routine maintenance visits, which are typically of short duration. The Facilities Manager can reduce the set point for occasions when the service technicians spend long hours, or the set point can be lowered temporarily by pressing a self-timer. Similarly, question the need to operate computer rooms such as server rooms at 20°C. Current thinking is that modern computer equipment can reliably operate at much higher temperatures of around 25–27°C
- Lock the control thermostats in the desired position and/or label them accordingly
- Control fan coils using room air temperature sensors, rather than return air sensors
- Where supplementary HVAC systems are connected to BMS, ensure that the systems have control interlocks to prevent the supplementary HVAC System counter-acting the central system
- Install automatic controls to shut down supplementary HVAC systems automatically. These can take the form of self-timers (typically set for 2 hours duration) or occupancy sensors. Ensure systems are labelled accordingly
- For rooms such as lift motor rooms and computer rooms, ensure that the space is well sealed (except for the provision of minimum outside air), shielded from solar gains. Install self-closers on doors and/or 'keep shut' signs.

6.9.3 REPLACING & UPGRADING

Consider the following issues before packaged HVAC Systems are replaced or upgraded:

- Ensure systems have high efficiencies (or COP-coefficients of performance) New systems must comply with current minimum efficiency performance standards (MEPS) refer to www.energyrating.gov.au.
- For Tenants' supplementary HVAC Systems that depend on base building services such as condenser water and tempered fresh air, ensure that motorised valves and dampers are installed to shut down demand when the systems are not in use. When the refrigeration compressor is not in operation, the condenser water valve should shut down. When the supplementary HVAC System is switched off, the tempered outside air damper should shut down. Such measures will enable central plant to be modulated, thereby saving energy
- Ensure that the above issues are covered in tenancy fit-out guidelines which request Tenant installed equipment to comply with such requirements and incorporate the necessary control interfaces
- Ensure systems operate only when required, incorporating automatic controls where possible. When ordering new HVAC units, ensure that the necessary interface card is specified, to enable interfacing with external controls such as occupancy sensors or manually operated self-timers.

6.10 Power Factor Correction

Refer to Appendix A for a description of power factor.

Mechanical services tend to have the biggest impact on the power factor in commercial buildings. Also, it is highly desirable for power factor correction (PFC) equipment to be monitored, a function typically carried out by the BMS. Therefore, this topic is addressed in this Guide, although PFC equipment is not classed as being part of HVAC Systems.

Where a facility has a maximum demand charge tariff in the electricity invoice, it is essential to install PFC equipment. This basically consists of banks of capacitors which are automatically switched by a PFC controller according to prevailing electrical load conditions. Apart from reducing maximum demand charges, improving the power factor at the mechanical services switch board (MSSB) will also enhance the capacity of the sub-main cable that feeds the MSSB, the main switch board and the supply transformer. It must be noted that the installation of PFC correction equipment will only improve the power factor upstream of the point of installation.

Where PFC equipment is installed, the target power factor should be around 0.98–0.99 coincident with the occurrence of maximum demand. If the corresponding power factor is less than 0.95, it is likely to be cost effective to investigate the causes and to improve the power factor – typically by replacing faulty capacitors, upgrading the existing capacitors and/or the installation of additional capacitors.

It is essential for Facilities Managers to be aware whether maximum demand charges are applicable to a building and if so, to monitor the power factor. Failure of power factor correction equipment can be very expensive in terms of maximum demand charges.

6.10.1 ENERGY CONSUMPTION

PFC equipment consumes very little energy and the installation of PFC equipment makes insignificant improvements to energy consumption for most office type buildings. The main benefit from PFC equipment is the reduction of maximum demand charges for the supply of electricity, where this type of tariff applies.

6.10.2 MAINTENANCE & OPERATION

The following issues are important for the efficient maintenance & operation of power factor correction equipment:

- Regularly monitor the PFC system for correct operation, especially during times of maximum demand
- Set up automatic alarm functions to warn of faults and loss of control. Use an independent system (a system which is separate from a fault signal available from the PFC controller) connected to the BMS, to monitor the power factor. Certain electricity authorities permit direct connection of the BMS to the utility meter, which measures power factor
- Rectify faults promptly.

6.11 Building Management Systems

Building Management Systems (BMS) control and monitor the operation of HVAC systems in buildings. Quite often, the BMS has the highest potential to deliver cost effective savings through the use of smart control strategies that improve HVAC system performance. Additional benefits from BMS include monitoring of key performance indicators (KPIs) and providing timely warning when HVAC equipment does not deliver the rated performance and systems don't perform efficiently. The BMS can be the most useful tool for all Stakeholders to verify the performance of systems and service delivery by the Maintenance Service Providers.

Energy Auditors can use BMS information set up as trend logs or graphs to monitor energy consumption and diagnose the reasons for abnormal performance. Facilities Managers can use BMS data for on-charging Tenants for after-hours usage of HVAC systems and for allocating costs. Maintenance Contractors can use BMS for monitoring certain parameters and KPIs for the purposes of condition based maintenance thereby reducing maintenance costs without compromising system performance or reliability.

Energy and water consumption can continuously be monitored by BMS and the system can either alarm or even take corrective action should certain parameters be exceeded. An example being the shutting down of a solenoid operated valve that supplies water to non-essential equipment such as irrigation systems, should a pattern of water consumption indicate a possible leak. Also possible is load shedding or load limiting where during certain times of maximum demand, the operation of equipment such as chillers and electrode humidifiers can be restricted.

Unfortunately, in many buildings, the full potential of BMS is not used and sometimes BMS are underused and neglected to an extent where they perform little more than time clock functions.

The functional description for the BMS is often inadequate, and the BMS is set up and commissioned poorly at the tail end of projects. BMS operators are often not given adequate training, therefore, are not familiar with important functions – some of which are complex and take time to understand. Documentation is not updated to keep up with changes made to the systems and trend logs are not set up for key parameters to identify non-performance. Control loops are very rarely optimised for efficiency and systems continue to perform on default settings. The combined effects from these issues to a Facilities Manager and Maintenance Contractor is that it may take a considerable amount of effort and specialist knowledge from a BMS Specialist Contractor, to get the system to deliver optimal comfort and energy performance. A Contractor tendering for a maintenance contract that has specified deliverables for maintaining performance ratings or enhancing efficiency would be well advised to obtain first-hand knowledge about the state of the existing BMS and to ensure that staff have familiarity with the type of BMS that is installed.

For a BMS to deliver its full potential for optimising energy consumption, the system has to be correctly specified, installed, commissioned and tuned. Continuous monitoring and maintenance including calibration of sensors and fine tuning are required by skilled contractors to ensure that BMS continue to perform optimally.

6.11.1 ENERGY CONSUMPTION

BMS components consume very little energy compared to the equipment they control. However, the BMS has a significant potential to save energy through effective control of HVAC systems.

6.11.2 MAINTENANCE & OPERATION

The following issues are important for the efficient maintenance & operation of BMS Systems:

- It is important for the Facilities Manager and Maintenance Service Provider to familiarise themselves with the capabilities and operational parameters of the BMS. If necessary, the services of a BMS Specialist will be required to update available information on O&M manuals, including producing a functional description for the control algorithms
- It is important for Maintenance Contractors to have access to the BMS, for HVAC system maintenance and operational purposes. The protocols and procedures for making changes to the BMS and documentation of any changes will need to be agreed between the Facilities Manager and the HVAC Maintenance Contractor. It is essential for key members in the Maintenance Contractors team to have a good working knowledge of the BMS operation including monitoring and trending functions. The HVAC Maintenance Contractor must allow to engage the services of a BMS specialist for services such as optimisation of control algorithms, re-programming, setting up reporting functions (such as for NABERS), monitoring and diagnostic screens
- It is essential that diagnostic screens are set up for the verification of key HVAC system functions including the economy cycle, operation of VAV boxes, modulation of fans and pumps through VSDs, chiller and boiler operation including flow temperature re-set and leaking valves
- Ensure HVAC equipment is correctly scheduled to operate only when required and local public holidays are programmed. Optimum start and stop functions must be included where appropriate. After hours operation must be restricted only to enable the zones requesting the operation of HVAC. After hours operation must be logged, especially if the building is to have a NABERS rating
- Ensure control parameters such as temperature, RH and operating times are not wasteful. Suitable temperatures for winter operation are 21–22°C, summer 23–24°C and for most office type applications the relative humidity can be allowed to 'float' between 35–60% RH and perhaps even beyond, depending on the building, its location and the type of occupancy. Areas such as lift and entrance lobbies and other transient areas where occupants spend relatively short periods of time can typically tolerate wider temperature deviations when compared to other areas. After hours operation should be limited to 1 hour per activation
- For main energy consuming plant such as chillers and boilers, programme the BMS to give secondary or overriding means of control (a belt and braces approach) to limit spurious operation. Examples are outside air temperature lock-outs for boilers, re-heat systems and chillers
- Ensure sensors are calibrated, at least annually and that sensors are not affected by extraneous factors including solar gains, heat output from office equipment, air leakage through unsealed cable entries.

6.11.3 REPLACING & UPGRADING

Consider the following issues before BMS Systems are replaced or upgraded:

- Avoid replacing like for like. By simply replacing an existing BMS with new hardware and graphics it is likely that some of the inefficient controls algorithms residing within the existing BMS are replicated and opportunities for gaining efficiencies are lost. It is essential that a holistic view is taken with a proper specification developed for the new BMS. Specifying a new BMS requires an in-depth knowledge and is much more complicated than specifying equipment such as a chiller, for which performance requirements can be easily stipulated in accordance with internationally accepted standards
- Ensure electricity, gas and water sub-metering is installed at key locations for major consumers such as mechanical services switchboards, chillers, cooling towers, humidifiers and boilers to monitor the performance of these systems and to automatically report wastage and to enable the identification of faults
- When producing a specification for a new system, all Stakeholders must work as a team and carefully evaluate the needs of the building, particularly the HVAC systems. The operational requirements and functions for monitoring key parameters and KPIs for performance based maintenance must be considered. Many energy smart control strategies have been developed

recently and these must be assessed against the HVAC systems installed within the building and specified accordingly

- Graphics, reporting pages for performance rating systems including NABERS and tools that enable easy diagnosis of non-performance must be specified
- Ensure that proper commissioning and verification of BMS performance is specified. Also important is monitoring and fine tuning over a 12 month period as well as training, technical support from established locally based service technicians and the provision of on–line assistance.

Further Information

1. CIBSE Guide H – Building Control Systems: ISBN 07506 504 78
2. AIRAH Application Manual: DA28 Building Management and Control Systems (BMCS) ISBN 978-0-949436-50-4.

6.12 Commissioning & Building Tuning

Commissioning is carried out after the installation of equipment and systems to ensure that they are tested in operation and perform safely, satisfactorily and efficiently.

HVAC equipment such as chillers, cooling towers, boilers and air handling units only operate under design conditions where they deliver maximum output, for relatively short periods of the year. Operation for most part of the year is under part load conditions, therefore, to ensure efficient operation, it is essential for commissioning to give attention to part load operation taking into account seasonal variations.

Systematic and thorough commissioning of HVAC Systems and their controls must be carried out after the installation and testing of new equipment. Depending on factors such as the time of year (which determines outside air temperatures) and the level of occupancy in the building (which determines internal heat loads), the initial commissioning may have to be carried out during conditions which are either simulated and/or non-representative. Following the initial commissioning, in order to obtain maximum performance and energy efficiency, it is important for building tuning to be carried out under part load and representative conditions where different systems interact with each other, e.g. the supply air fan in an AHU might deliver the design volume flow rate, but under real conditions where the VAV boxes throttle down, if the fan does not modulate satisfactorily, this is likely to lead to energy wastage.

Commissioning of HVAC systems and controls is an area which has often been neglected due to a lack of awareness, low prioritisation and poor competencies of staff, with major consequences of energy wastage and poor performance.

Green Star and NABERS requirements have recently highlighted the importance of proper commissioning. The industry is now more aware of the necessary resources including adequate planning and programming, the use of trained commissioning technicians who are familiar with standards, the use of proper equipment and the availability of comprehensive documentation which are all essential to achieve a good outcome. At present, reference is made to CIBSE and ASHRAE commissioning guides, however, AIRAH has just published a commissioning guide for use in Australia.

Building tuning should be carried out during the defects liability period, together with monitoring of the systems and tracking the environmental performance ratings of the building.

Re-commissioning (or re-tuning) is carried out on older buildings, which have been in operation for a number of years and is often one of the most cost effective methods for improving energy performance. Re-commissioning essentially identifies wasteful operational practices (such as ad-hoc adjustment of control set points) and control inadequacies (such as poor sensor calibration, faulty field items including motorised dampers and valves) and corrects them. Re-commissioning also covers the implementation of “smart” BMS controls strategies, which may not have been implemented in the original system. Since re-commissioning mostly involves interrogation and programming of the BMS, this is generally an inexpensive and non-disruptive process. Re-commissioning also identifies whether retro-commissioning is required and if so, identifies the areas that require this. E.g. whether air side or water side commissioning is required, whether an entire building needs to be re-commissioned or whether problems exist only in certain floors.

The term “*retro-commissioning*” refers to re-commissioning of existing buildings, often taking into account changes to heating and cooling loads that may have occurred over the years. Tenancy fit-outs may also have affected the air and water side balance of the HVAC systems together with ad-hoc attempts to fix problems by altering the settings on balancing valves and dampers.

Where no existing information is available from operating and maintenance manuals, it is important for the Facilities Manager to seek specialist advice and to ascertain the key system parameters including air and water flow rates to which a system is to be retro-commissioned.

6.12.1 MAINTENANCE & OPERATION

The following issues are important for the efficient maintenance & operation of HVAC Systems:

- Ensure that commissioning data is available for HVAC systems, together with details about operation and system drawings showing location of key system components including balancing valves and dampers. This information is typically available in operating and maintenance manuals
- Perform thorough monitoring of systems through the BMS (as described in the previous section), checking for evidence that the air side and water side balance of the system is satisfactory
- If balancing is suspect, carry out checks using the services of a Commissioning Specialist and determine the extent of the problem and determine whether re-commissioning a sub circuit, a floor or a zone is likely to remedy the fault or whether more extensive commissioning is required
- Carry out retro-commissioning when required. If financial constraints prevent total system re-commissioning, at least carry out a partial re-commissioning on a staged basis – floor by floor or circuit by circuit

6.12.2 REPLACING & UPGRADING

Consider the following issues when HVAC systems are replaced or upgraded:

- When upgrading HVAC systems, this is an ideal opportunity to assess the degree of commissioning and re-tuning of systems that is necessary. Even if one major component such as a chiller is replaced, it is beneficial to assess the water flows within the systems it operates, including chilled water and condenser water flow rates
- It is essential for Design Engineers to include detailed commissioning specifications in tender documentation. For new projects where Green Star requirements apply, the services of an Independent Commissioning Agent (ICA) are essential along with tuning. For larger HVAC upgrade projects, the services of an ICA may be beneficial to manage the process including the development of commissioning plans and carrying out tuning during the defects period. For existing maintenance contracts, it may be worthwhile to enquire whether the Maintenance Contractor has available resources to provide commissioning services
- Allow adequate resources and time for commissioning and the production of documentation. It is important to resist any pressure to reduce time allocated for commissioning due to time overruns during the earlier stages of a project.

Further Information

1. AIRAH Application Manual: DA27 Building Commissioning. ISBN 978-0-949436-51-1

6.13 Trends in HVAC Design over the past 20 Years

Air-conditioning design has changed significantly over the last 20 years, driven by technological innovation and in particular by the improvement in building control systems. This does not preclude older buildings from achieving high levels of efficiency but often means that a degree of updating is required to achieve good results. Some notable trends include:

- Variable speed drives. Variable speed drives (or VSDs) have become a ubiquitous feature of modern air-conditioning systems, particularly as a means of controlling fans and pumps. Twenty years ago VSDs were far more expensive, and control systems were less capable of making good use of them. As a result fan control often used less efficient methods of capacity modulation (throttling with dampers, inlet guide vanes, or cycling on and off). Pumps typically were throttled to achieve flow control. The use of variable speed drives enables flow control to be undertaken both more accurately and more efficiently
- Building control systems. Through to the early 1990's most building controls were either based on stand-alone electric controls or pneumatic controls (which operate based on compressed air). Indeed, it is only in the past 10 years that the full-electronic building control system has gained complete ascendancy. With the advances that have been made in computer technology generally, the available control systems are immensely more powerful than the older systems. This is particularly important for

enabling the operator to "see" what is happening in the many hundreds or even thousands of separately controlled devices within the building. A modern, well-configured building control system is an invaluable tool for enhancing the efficiency of a building. However, the complexity of such systems often means that this potential is unrealised and indeed quite difficult to comprehend for building operators, contractors and consultants. As a result the "tuning" of building controls is often one of the best areas for energy savings in office building HVAC

- Chillers. Chiller technology has maintained a steady state of advancement for many decades. As a result, there has been a significant improvement in average chiller efficiency over the past two decades, probably in excess of 30%. Furthermore, with the introduction of variable speed chillers, particularly large improvements in efficiency have been made when chillers are operated at part load and under conditions of increased chilled water temperature and/or reduced condenser water temperature. It is not unusual for the replacement of an older standard technology chiller by a new leading-edge technology chiller to yield savings of up to 50%
- Variable speed compressor direct expansion cooling systems. The application of variable speed drives has also had a significant impact in the performance of small air-cooled packaged cooling systems such as split systems. The use of variable speed technology (also known in this context as inverter-drives) can improve system efficiency by greater than 30%
- HVAC system types. There has been a gradual transition in air-conditioning system types over the past two decades. Some notable examples include:
  - Dual duct systems: These systems, which create hot and cold air and mix them together to cool or heat the zones of the building, were quite popular through until about 20 years ago, but are no longer built, mainly due to efficiency issues and high capital costs. There are, however, some quite efficient variants of this design which can be used as a model for retrofit for those buildings still with original systems in place; in particular the use of variable volume control and separate fans for the hot and cold ducts
  - Variable air-volume systems. This system type remains the most common air-conditioning system for larger buildings, and has been throughout most of the past two decades. Changes in the system design over this time have been incremental and largely relate to improved controls
  - Induction units. Induction units were still quite popular in the 1990s as a means of providing a relatively high power density of cooling for perimeter zones. Many buildings still have induction units around the perimeter and either a constant or variable air volume system in the centre zone. Induction units, however, fell out of favour about the turn of the century due to maintenance, efficiency and cost concerns. However, with the advent of "active chilled beams" – which are in effect an improved induction unit – there has been somewhat of a resurgence in the use of this technology, again as a perimeter air-conditioning system
  - Variable refrigerant flow systems. For small buildings that do not merit the complexity of a chiller, the typical solution has been the use of packaged air-conditioning systems. In the past 10 years, variable refrigerant flow systems have become available as an alternative solution. These systems operate like a package unit at a fundamental level but can connect multiple internal units to a single external unit (as opposed to a packaged unit which is generally limited to one internal unit for one external unit). This enables better compressor technology to be used for the single external unit, and also can permit the transfer of heating and cooling between zones to reduce overall system loads. The result is a highly efficient system for small to medium buildings
  - Passive chilled beams. Passive chilled beams circulate high temperature chilled water through open heat exchanges mounted overhead of office occupants. The chilled water induces a cool downdraft which imparts cooling. This system, which has a relatively long track record in Europe, has been in use in Australia since around 2005 and has a reputation for the delivery of high-efficiency outcomes. It is best suited to buildings with low loads throughout and in particular limited perimeter loads, as the overall cooling power density available from this system is relatively low.

Appendices

APPENDIX A – DEFINITIONS OF KEY WORDS

Asset Register

Database (or a list) of building services equipment (or plant), that contains information such as asset identification number, equipment function, manufacturer and model, duty, age, cost and location. This Guide promotes the inclusion of an *Environmental Impact Rating (EIR)* for equipment in the asset register which rates the environmental impact and potential for upgrade in key HVAC equipment that has a significant impact on energy and water consumption.

Base Building Services

Base building services are also known as *central services*. These are common services provided by the building owner that serves all occupied spaces (or tenancy areas) and include the HVAC systems installed within the occupied spaces except for any *supplementary air conditioning* installed by the building occupants.

In a multi tenanted building the building owner has responsibility for maintaining and operating the base building services. There may be cases where a tenant is occupying a whole building and the agreement between the parties is such that the tenant assumes some of the control over the base building services. The degree of control will vary across different practical situations and commercial agreements.

BCA Section J

The Building Code of Australia – refer to www.abcb.gov.au The BCA is now referred to as the National Construction Code (NCC). Section J of the NCC covers energy efficiency requirements for buildings. It contains information relating to the mandatory requirements for energy efficiency of HVAC equipment such as chillers, boilers, pumps and fans and also covers thermal insulation. New buildings must comply with Section J requirements. Major refurbishments (typically >50% floor area) must also comply with Section J requirements. When replacing existing HVAC equipment, it is good practice and often cost effective to comply with Section J requirements, even when it is not a mandatory requirement. Therefore, compliance with Section J is recommended in Chapter 6 of this Guide, when replacing certain HVAC equipment.

Benchmarking

Benchmarking is the comparison of a building's energy or water consumption with similar buildings and/or industry best practices. Typical benchmarks for buildings are expressed in kWh/m^2.y or MJ/m^2.y for energy consumption, kg CO2–e/m^2.y for greenhouse gas emissions and ML/m^2.y or ML/occupant.y for water consumption. When comparing the energy or water performance of an existing building with available benchmarks, it is important to establish whether the systems are similar and a comparison of 'apples with apples' is made by normalising for variances such as climate, operating hours and operating conditions. Refer also to *Key Performance Indicator (KPI)* and *NABERS*.

Breakdown Maintenance

Also known as *Reactive Maintenance*, where remedial work is carried out when equipment fails in operation, hence, a form of *Unplanned Maintenance*. If remedial work is carried out to equipment in response to a situation that may have serious consequences that could impact health and safety – this aspect of breakdown maintenance is referred to as *Emergency Maintenance*. Breakdown Maintenance will not deliver *High Performance Buildings*, and is expensive in the long term leading to the depreciation of asset value. Failures can sometime have catastrophic consequences such as flooding and explosions which may require the building to be evacuated.

Building Energy Efficiency Certificate

From 1 November 2011, sellers or lessors of office space greater than 2,000m² are required to disclose a current Building Energy Efficiency Certificate (BEEC) if they are selling, leasing or sub-leasing the office space. A BEEC will include a NABERS energy rating for the building, an assessment of tenancy lighting in the area of the building that is sold or leased and general energy efficiency guidance to Building Owners and Tenants regarding typical energy efficiency opportunities in commercial office buildings. Refer to www.cbd.gov.au for further details.

Building Occupant

Refer to *Tenant*

Building Owner

The Building Owner has ultimate responsibility for legal and compliance issues for a building. The Building Owner has the most influence for making a building sustainable. This includes responsibility for establishing environmental and maintenance policies for the building and ensuring adequate resources are made available. In doing so, the Building Owner must take account of the Building Occupants requirements and aspirations if the tenancy is to be secured over the long term.

Building Tuning

The process of carrying out adjustments to systems installed in buildings to ensure peak performance is delivered and maintained. The initial building tuning period for a building typically covers twelve months after initial commissioning and hand over. During this period, the performance of HVAC and other systems is optimised by making adjustments to air and water flow rates, system parameters and control algorithms taking into account issues including part load performance, seasonal changes in temperature and specific occupant requirements such as after-hours operation. Building monitoring and tuning needs to be an ongoing activity for a building to deliver high performance. Building tuning is awarded two credit points under the *Green Star* rating system. Also refer to Commissioning.

Building Users Guide

A document that is written to assist Building Occupants understand important functional and operational aspects of a building and its services such as HVAC, lighting, lifts, fire alarm and suppression, security and access control systems. The building user guide must clearly describe the design intent, functionality and operational requirements of key features that reduce the environmental impact of a building including energy and water saving systems. In the past, Building Occupants had no way of obtaining this information apart from referencing operating & maintenance manuals, which by their nature are complex and cumbersome documents, not readily available to Building Occupants. The inclusion of a building users guide is awarded a credit point under the *Green Star* rating system. The building user guide must be readily available to the Building Occupants.

Central Services

Refer to *Base Building Services*.

Commercial Building Disclosure

CBD is a national energy efficiency program that requires from 1 November 2010 for sellers or lessors of office spaces greater than 2,000m² to obtain and disclose an up to date NABERS energy rating. It also requires from the 1 November 2011 the disclosure of a *Building Energy Efficiency Certificate (BEEC)*. Refer to www.cbd.gov.au for more details.

Commissioning

Commissioning is carried out after the installation of equipment and systems to ensure that they are tested in operation and perform safely, satisfactorily and efficiently. Commissioning is essential for HVAC systems to deliver optimal performance and provide energy and water efficiencies. Proper balancing of air and water flows to design specifications, the correct setting up of BMS controls and maintaining good documentation are key requirement of the commissioning process. The term *Re-Commissioning* (or re-tuning) is used when an existing system is commissioned after a period of time has elapsed since the original commissioning was carried out, taking into account of any minor changes to system parameters that may have occurred. *Retro-Commissioning* applies when existing buildings or systems have undergone major changes or haven't had previous commissioning. Also refer to *Building Tuning*.

Commissioning Specialist

A Commissioning Specialist is responsible for the verification of the building installation and its operation, in accordance with the requirements of the Designer. An *Independent Commissioning Agent (ICA)* is a Commissioning Specialist with commissioning management experience who is appointed to report directly to the Building Owner (or the Tenant for tenancy fit-out work) with regards to ensuring that commissioning work is carried out in a systematic and thorough manner in accordance with the design intent. To obtain best results, it is important for the ICA to be independent from the design team and the installation contractor. The engagement of an ICA for the commissioning process is awarded a credit point under the *Green Star* rating system.

Defects Liability Period

A period of time (typically twelve months) following practical completion of a building construction and/or a services installation. During the DLP, the Installation Contractor is responsible to remedy any issues or defects that arise due to faulty workmanship or materials. For most HVAC installations, it is typical for the Installation Contractor to carry out planned maintenance during this period, although in certain circumstances such as the replacement of existing plant, planned maintenance may be carried out by the incumbent Maintenance Contractor with any breakdowns and non-performance issues being rectified by the Installation Contractor.

Contractors are increasingly asked to deliver target environmental performances (such as NABERS ratings) during the defects liability period and this has created a focus on efficient operation & maintenance.

Degree Days

Degree-days are the summation of the differences between prevailing outdoor temperature and a reference (or base) indoor space temperature, carried out over a specified time period. Cooler the weather is – higher the number of heating degree days, warmer the weather is – higher the number of cooling degree days.

The energy consumed by HVAC Systems in office type buildings is heavily dependent on external temperature, which in turn depends on geographical location and temperature variations due to season and day/night time. The analysis of heating energy consumption with *heating degree days* and cooling energy consumption with *cooling degree days* provide the means to analyse how efficiently heating and cooling systems operate in a building.

The definition of the base temperature is important. For typical office type buildings, when the ambient temperature exceeds 16°C, space heating is not required, because internal heat gains from lighting, office equipment and people, provide sufficient heat to maintain comfort conditions. Therefore, for typical office space heating applications, heating degree days are compiled to a base temperature of around 16°C. The reverse applies to cooling degree days with typical office areas (excluding areas with high heat gains such as in computer rooms) not requiring air conditioning at ambient temperatures below 18°C.

Historical heating and cooling degree days can either be obtained from weather bureaus (such as BOM) or complied from published weather data using equations. Where BMS are installed in buildings, this gives the capability for the system to automatically calculate the heating and/or cooling degree days and to trend KPIs such as energy consumption/degree day.

The topic of degree day analysis is covered thoroughly in CIBSE TM41: Degree Days: Theory and Application which is available as a free download from www.cibse.org.

Documentation

Refers to information including operating & maintenance manuals, commissioning data, drawings, asset registers, service log books and any other data which is important to maintain and operate HVAC systems efficiently. Documentation also includes information that is necessary to verify the performance of a building, such as key data necessary to perform a NABERS rating.

EEGO

The EEGO Policy is administered by the Department of Climate Change and Energy Efficiency (DCCEE). and applies to all Commonwealth departments and agencies covered by the *Financial Management* *and Accountability Act 1997* and all agencies and statutory bodies covered by the *Commonwealth Authorities and Companies Act 1997* and whose operations are substantially budget *dependant* (that is, more than half of its funding is derived directly or indirectly from Commonwealth funds).

The EEGO Policy sets out the minimum energy performance standards applicable to Government office buildings that are new, have undergone major refurbishment affecting ≥2,000m² or are subject to a new lease (or MOU where the building is Government owned) of greater than two years duration, including options.

The National Australian Built Environment Rating System (NABERS) scheme is used by the EEGO policy as a methodology for measuring the ongoing level of energy efficiency of office buildings.

The EEGO policy requires each agency to report its energy consumption against core performance indicators.

The requirements to be included in lease agreements and MOUs for new office buildings, major refurbishments and new leases over 2,000m² are:

- a mutual obligation to achieve and maintain the relevant NABERS Energy or equivalent performance standard
- an annual NABERS Energy (or equivalent) performance validation by an independent assessor
- separate on market status digital metering of tenanted areas and central services (and computer centres where cost effective)
- establishment of a formal management committee comprising tenant and building owner representatives (or integration into an existing building management committee)
- development of an Energy Management Plan outlining minimum procedures required to maintain the relevant performance standard
- remedial action/dispute resolution clauses.

Departments and agencies are required to note in their annual energy intensity report if any of these elements were not included in a lease for a building over 2,000m² and with a lease term of over two years.

For more detailed information refer to *http://www.climatechange.gov.au/publications/energy-efficiency/eeo-in-government-operations-policy.aspx*

Emergency Maintenance

Refer to *Breakdown Maintenance*.

Energy (or Water) Audit

A survey and analysis of a building's energy (or water) consumption to establish how efficiently these resources are being used and comparison of performance with similar buildings where possible. An energy audit also identifies energy saving opportunities as a prioritised list with payback periods. Energy audits are typically carried out in accordance with AS/NZS 3598:2000, which describes three levels of audits ranging from Level 1 to Level 3 depending on the extent of survey and analysis. A water audit would focus on water savings. There are no accepted standards for water audits although major utility providers operating in the States and Territories have developed templates for carrying out and reporting water audits.

Energy (or Maintenance) Auditors

Energy or Maintenance Auditors may be commissioned by the Facilities Manager or the Building Owner to carry out energy or water audits on buildings or to assess the effectiveness of the service provided by Maintenance Contractors. Maintenance audits may also be requested by Tenants, who want assurance that the Building Owner is maintaining the central services in a safe and efficient manner, in accordance with lease conditions. Energy or Water Audits may also be a requirement in *Green Lease Schedules*.

Energy Manager

A person appointed by the Building Owner or Facilities Manager to focus on managing energy (and water) costs and consumption. The Energy Manager often has responsibility for negotiation of utility purchase contracts and for monitoring and control of energy consumption and costs through the implementation of energy management strategies. The functions of an Energy Manager are typically combined within the role of the Facilities Manager, with larger facilities and companies managing property portfolios likely to be employing Energy Managers.

Energy Star Ratings

The efficiency of office equipment can be gauged from Energy Star Ratings. Energy consumption from office equipment such as PCs, monitors, copiers and scanners can account for 30–40% of total consumption within tenancies. Wastage can be minimised, especially during standby mode, by specifying office equipment which comply with the latest Energy Star Ratings. Australia tends to follow US star ratings by twelve months. Refer to www.energystar.gov.au and www.energystar.gov (the United States site) for more details.

Facilities (or Property) Manager

The Facilities Manager is employed by the Building Owner, to be responsible for the operation of a property (or facility) and its services. The FM's responsibilities range from day to day operation & maintenance, complying with statutory requirements, strategic planning and maintenance management. The FM's role will also have responsibilities for sustainability and enhancing a buildings performance which includes improvements to energy and water efficiencies.

Refer also to Property Manager.

Greenhouse Emission Factors

These values are published by the DCCEE and are available at www.climatechange.gov.au under National Greenhouse Accounts (NGA) Factors. The most common greenhouse gas associated with the operation of HVAC systems in commercial office buildings is CO_2, although other emissions such as refrigerants, may also be relevant to larger facilities. CO_2 emissions caused by a facility can be attributed to electricity use and the consumption of fossil fuels such as gas (for space heating and domestic hot water) and diesel (for standby generators). The CO_2 emissions caused by electricity generation vary from state to state, depending on the type of fossil fuel consumed – brown coal, black coal or natural gas, and the proportion of electricity produced from renewable sources such as hydropower, solar and wind.

Green Lease Schedule

The Commonwealth Green Lease Schedules (GLS) are intended to form part of lease documentation (or MOUs where the Government owns the building). Some State and Territory Governmental Organisations (Tenants) are also developing customised versions of Green Lease Schedules, which they sign with Landlords.

The Commonwealth Green Lease Schedules are designed to ensure that buildings are operated at the required level of energy efficiency and cover the five essential elements discussed at paragraph 5 above.

DCCEE has produced a number of standard templates that account for different types of leases (gross or net) and the proportion of the building that is tenanted. The GLS templates also contain optional clauses covering water conservation, waste management and other issues for those agencies who wish to capture broader building sustainability issues in their leases.

Standard EMP templates have also been produced by DCCEE. The GLS and EMP templates can be downloaded from the Department's website: www.greenhouse.gov.au/government.

Green Star

An environmental rating system (or tool) developed by the GBCA for offices and other buildings. 'Green Star Office' is specific to office type buildings and it gives credits for implementing energy and water saving measures in new and refurbishment building projects through proper design, installation and commissioning of HVAC Systems. Green Star has raised the importance of key issues which have traditionally been neglected. These have a significant impact on energy and water consumption in buildings and include proper *Commissioning, Building Tuning*, and good *Documentation* including the development of *Building User Guides*. Refer to www.gbca.org.au for more details.

Gross and Net Rent

Some lease transactions are based on a gross rent where the operating and maintenance costs associated with providing the base building services are paid by the building owner and these costs are included in the rents charged to the occupants. Energy costs are absorbed within the gross rent (apart from any costs directly payable by an occupant whose premises are separately metered and who is required by the lease or licence to make direct payment for energy consumed in the leased or licensed area). A gross rent approach provides an incentive for building owners to adopt the cost saving opportunities available through the implementation of energy efficiency measures.

Some lease transactions are based on net rent where the building occupant pays for a range of outgoings. While the heads of outgoings will vary from transaction to transaction they can operate to capture the energy costs associated with the base building services (as well as the energy costs for the tenancy areas if those areas are not separately metered).

Where the rent is semi gross the building owner recovers the escalation in outgoings above a nominated outgoings base year. This base year is selected at the start of the lease and is usually the last reconciled outgoings year prior to lease commencement, which is usually the previous financial year to the start of the lease (because it is fully reconciled and known as a set value). The base year can be updated through the term of the lease based on the agreed lease provisions. As the semi gross lease proceeds through its term, the tenant pays the escalation of the outgoings above the nominated base year. Again the heads of outgoings can vary from transaction to transaction and they can capture the energy costs associated with the base building services (as well as the energy costs for the tenancy areas if those areas are not separately metered).

Generally the building owner has the most influence for ensuring that buildings operate sustainably and has the potential to motivate and empower all stakeholders to deliver efficiencies through best practice operation and maintenance. The policies and strategies set by the building owner drive the process for setting up and implementation of maintenance contracts and efficiency measures.

High Performance Buildings

Buildings that perform much better than average in terms of energy and water efficiency, indoor environment quality (IEQ) and system reliability. Apart from lower utility costs, such buildings also deliver benefits to occupants through better health, motivation and productivity. They also retain their asset value by being viewed as desirable properties.

Independent Commissioning Agent (ICA)

Refer to Commissioning Specialist.

Key Performance Indices (KPI)

Often, the words *KPI* and *Benchmark* are used to describe the same thing, however, there are subtle differences. In this Guide, the term KPI refers to certain performance indicators, typically at a lower level than a benchmark, which indicates how efficiently a particular aspect of an energy (or water) consuming system is performing. KPIs are analogous to 'feeling the pulse' or 'measuring the blood sugar levels' of buildings, whilst benchmarks refer to the 'state of health' of the building. If the performance of a building is unsatisfactory (represented by poor benchmark performance), if KPIs are set up and monitored (ideally through the BMS), they provide useful information to Facilities Managers, Maintenance Contractors and Energy Auditors to analyse the causes for the poor performance and to implement measures to improve efficiency.

Life Cycle

The time interval between a building (or system) being designed through to its disposal. Life cycle costing includes operating (= maintenance + energy) costs and is a truer representation of cost over the long term rather than using capital or first cost. For most HVAC equipment, the capital cost is only a small proportion of the life cycle costs. Therefore, when considering the installation of new or replacement plant it is important to consider life cycle costs rather than capital cost.

Maintenance

Technical, supervisory and administrative activities that are carried out on plant and equipment in order to retain performance and ensure that systems perform reliably and satisfactorily during operation. Types of maintenance can be sub-divided into *Planned Maintenance* or *Breakdown Maintenance*.

Maintenance Contractor (Service Provider)

An organisation engaged to perform maintenance on equipment within a building, complying with statutory requirements and in accordance with a maintenance specification and contract. Some buildings may have maintenance staff directly employed by the Building Owner or the Facilities Manager. Other buildings have Maintenance Contractors appointed.

Maintenance Logbook

A record of ongoing testing, events, parameters, settings including servicing and maintenance from the date of installation and commissioning to the end of life of a system. Equipment log books are dedicated to major equipment such as chillers, boilers and cooling towers. Maintenance Log Books should be retained on site for easy reference by all Stakeholders involved in HVAC maintenance activities.

Maintenance Policy

A policy developed by the Building Owner that stipulates maintenance requirements and may include references to health and safety, energy and environmental policies, giving consideration to any specific requirements of lease agreements. It is essential for the maintenance policy to incorporate sustainability objectives and obtain corporate endorsement from the highest levels, in order to secure the necessary funding and good governance necessary for energy and water efficient maintenance. The Building Owner has a crucial role to play in determining the degree of maintenance to be carried out on HVAC systems, therefore, it is essential that the policy of the Building Owner are documented and passed on to other Stakeholders to seek their commitment and action.

MEPS

Minimum Energy Performance Standards are set by the Commonwealth. These apply to a range of equipment and appliances including air conditioners, chillers and motors. MEPS apply to single-phase and three-phase air-conditioners of the vapour compressor type up to a rated cooling capacity of 65kW. Refer to www.energyrating.gov.au.

NABERS

NABERS is a performance based rating system for existing buildings. NABERS rating systems are available for Energy, Water, Waste and Indoor Environment Quality. NABERS rates a building on the basis of its measured operational impacts on the environment, and provides an indication (0–6 stars) of how well a building is managing these environmental impacts compared with buildings of similar type, in similar geographic locations. An un-accredited NABERS energy and NABERS water rating can be performed by anyone, using the online calculator, to compare the energy or water performance of their building with similar buildings. An accredited NABERS rating, that can be publicly displayed, can only be performed by an accredited NABERS assessor. Refer to www.nabers.com.au for more details.

A NABERS energy or water rating is a *Benchmark* which compares a building's performance with regards to energy or water consumption, normalising for factors that cover geographical location, building floor area, number of occupants, occupancy hours and greenhouse coefficient of the energy consumed.

NCC

National Construction Code. Refer to BCA Section J.

NGERS

The National Greenhouse and Energy Reporting Act (2007) is administered by the *DCCEE* for the reporting of annual greenhouse gas emissions and energy consumption. NGERS is a mandatory requirement that applies to facilities or corporate groups whose emissions, energy consumption or production levels are higher than the applicable thresholds. Refer to www.climatechange.gov.au for more details.

Planned Preventative Maintenance

Maintenance that is carried out in a planned manner with a view to preventing equipment failure, improving system reliability and availability. For energy and water efficiencies to be delivered it is essential for maintenance of HVAC Systems to be carried out on a planned or performance based approach rather than an unplanned or reactive basis. Planned preventative maintenance may be carried out either at fixed intervals (or schedules) – referred to as scheduled maintenance or when certain pre-determined parameters are exceeded – referred to as *performance (or condition) based maintenance*. BMS systems can play an important role in performance based maintenance, helping to improve reliability and efficiency in a cost effective manner.

Power Factor

Is relevant to the electricity invoice for a building. Power Factor is the ratio of: 'true' electrical power (kW) / 'apparent' electrical power (kVA). HVAC equipment has electrical motors (which are inductive loads) that reduce a buildings power factor, thereby increasing the electricity demand (kVA). Some electricity suppliers charge for the monthly maximum demand (kVA), in addition to the electrical energy (kWh) consumed and should this be the case, these demand charges are identified separately on the electricity invoice. Power Factor is improved by the installation of power factor correction equipment, which typically consists of capacitor banks and the associated controls. Improving power factor reduces constraints to the electricity supply distribution networks and also can improve the capacity of the electrical reticulation systems within the building, including transformers, switchboards and sub-mains cables.

Property Manager

The term Property Manager is sometimes used for the person or entity that negotiates tenancies sets up lease contracts and collects rent on behalf of the Owner. Often the roles of Facilities Manager and Property Manager are combined.

Refer also to Facilities Manager.

Reactive Maintenance

Refer to *Breakdown Maintenance*.

Service Level Agreement

A contractual agreement between the *Building Owner* and/or *Tenant* and the *Maintenance Service Provider*, which defines the level to which the performance and condition of the plant and equipment will be maintained in accordance with the maintenance policies and strategies. Typically, SLAs describe the performance outcomes required from maintenance contracts.

Supplementary HVAC

These are HVAC systems which are typically installed, operated and maintained by Tenants. Such systems serve areas such as meeting rooms having high occupant densities and computer rooms, which have requirements that are beyond those provided by the *Base Building Services*. Supplementary HVAC Systems are powered through the Tenant's utility metering. Some supplementary HVAC Systems are connected to *Base Building Services* operated by the *Building Owner*. These include the Tenant's condenser water loop and Tenant's supplementary fresh air and exhaust air systems. The proper design and operation of supplementary HVAC Systems is important to prevent these systems making excessive demands from Base Building Services and/or counteracting (or 'fighting') them, thereby causing energy wastage.

Tenants (Building Occupants)

Tenants are the ultimate Clients who pay rent to the *Building Owner* for the right to occupy the tenanted area during the lease period. Buildings are sometimes occupied by those who own them, in which case the words Building Occupant are relevant.

Unplanned Maintenance

Refer to *Breakdown Maintenance*.

APPENDIX B: CHECKLIST – BUILDING OWNER

Task	Action	Section in Guide	
Set-up Sustainability Policies			
1	Prioritise efficient HVAC operation & maintenance.	1.2, 1.5	☐
2	Ensure environmental & maintenance policies are in place, taking into account aspirations of Building Occupants. Provide corporate direction for sustainability objectives.	2.1, 2.2	☐
3	Ensure that agreed service conditions in leases (temperature, humidity, after hours operations) are not wasteful. Where necessary, negotiate with Building Occupants.	3.1	☐
Develop Maintenance Strategies			
4	Ensure maintenance strategy is developed.	2.3	☐
5	Ensure sustainability benchmarks & HVAC KPIs are developed.	2.4	☐
6	Consider incentives to Maintenance Contractors for enhancing efficient operation & maintenance of HVAC systems, rather than penalties for non-performance.	2	☐
7	Ensure adequate energy and water metering is installed.	2.5.3	☐
8	Where an existing contract has a long tenure remaining, discuss and negotiate energy saving opportunities with the Maintenance Contractor.	2	☐
Allocate Necessary Resources			
9	Allocate a budget to enable efficient maintenance to be carried out.	2	☐
10	Employ suitably trained staff to procure and manage HVAC maintenance & operation. Seek professional advice where necessary.	2	☐
Building Operation			
11	Ensure Building User Guide is developed and distributed to Building Occupants.	4.4	☐
12	Ensure Tenancy Fit-out Guidelines are developed and are complied with.	4.5	☐
13	Ensure key documentation is in place with easy access to contractors: O&M Manuals, As Fitted Drawings, Maintenance Log Books, Building User Guides and Commissioning Data.	4	☐
Monitor Progress			
14	Have regular progress meetings with the Facilities Manager, encourage a team effort with all Stakeholders carrying out their responsibilities.	1.5	☐
15	Monitor HVAC KPIs and building performance targets. Ensure corrective action such as re-commissioning and fine tuning are carried out where necessary.	2.4.3	☐
16	Carry out Energy & Water Audits, using Consultants if necessary.	2.5.4	☐

APPENDIX C: CHECKLIST – FACILITIES MANAGER

Task	Action	Section in Guide	
Set up Policies			
1	Confirm or develop maintenance & environment policies with Building Owner. Seek corporate endorsement.	2.1,2.2, 2.3	☐
Allocate Resources			
2	Develop realistic maintenance budget with Building Owner.	1.5.2, 2.3.3	☐
3	Ensure adequate resources are available to specify, procure & manage maintenance contract. Seek professional advice where necessary.	1.5.2, 2.3.3,	☐
Develop Maintenance Strategy			
4	Implement maintenance strategy.	2	☐
5	Develop HVAC KPIs and building performance targets with Building Owner.	2.4.3, 3.1	☐
6	Offer incentives to Maintenance Contractors for enhancing efficient operation & maintenance of HVAC systems, rather than penalties for non-performance.	2.3.2. 2.4.4	☐
7	Prioritise actions that would improve efficiencies and make cost savings. If necessary perform Energy & Water Audits.	2.5.4	☐
Prepare Documentation			
8	Ensure that an up to date Asset Register is available.	4.1, 4.6	☐
9	Develop Environmental Impact Rating (EIR) for HVAC equipment.	4.7	☐
10	Ensure key documentation is in place with easy access to contractors: O&M Manuals, As Fitted Drawings, Maintenance Log Books, Building User Guides and Commissioning Data.	4	☐
Procure Maintenance Contract			
11	Decide on maintenance contract type to be adopted and prepare maintenance contract document. Seek professional advice if necessary.	2.4, 2.5	☐
12	Check prospective Maintenance Contractors' Environmental Policy, for alignment with the requirements for the Building.	2.1, 2.4, 2.5	☐
13	Check prospective Maintenance Contractors' track record with efficient HVAC maintenance.	2.4, 2.5	☐
14	Check prospective Maintenance Contractors' capability on BMS & Controls Systems.	2.4, 2.5	☐
15	Check prospective Maintenance Contractors' business management & reporting systems.	2.4, 2.5	☐
Communication			
16	Ensure robust communication and reporting methods are in place between the Stakeholders.	1.5	☐
17	Prioritise maintenance call outs and response times for issues that waste energy & water.	2.4.4	☐

Task	Action	Section in Guide	
Maintenance Management			
18	Check that the Maintenance Contractor has adequate resources and supervision to deliver the specified outcomes.	2.4, 2.5	☐
19	Discuss with Maintenance Contractor and agree sustainability benchmarks and HVAC KPIs.	2.4	☐
20	Check the required Maintenance Logbooks are in place and are being updated.	4.1, 4.3	☐
Monitoring			
21	Ensure sub-metering is in place to monitor electricity, gas and water consumption flows throughout the building.	2.4, 2.5.3, 6	☐
22	Regularly check on KPIs. Use readily available means such as ½ hour time of use data from the electricity utility companies, to check unusual consumption patterns during public holidays and after-hours.	2.4.3, 3.2	☐
23	Ensure Maintenance Log Books are in place for major HVAC equipment and are being updated.	4.1, 4.2, 4.3	☐
24	Review HVAC maintenance procedures.	2.5	☐
25	Carryout maintenance audits and reviews of maintenance practices.	2.5.2	☐
Building Operation			
26	Develop Building User Guide and ensure its distribution to Occupants.	4.4	☐
27	Ensure Tenancy Fit-Out Guidelines are issued and are enforced.	4.5	☐
28	Ensure that agreed service conditions in leases (T, RH, after hours operations) are not wasteful. Re-negotiate with Tenants, where necessary.	3.1	☐
29	Increase temperature dead bands in areas such as entry lobbies, lift motor rooms and in office areas where possible.	6.9	☐
30	Monitor HVAC KPIs and take corrective action where necessary. Also track NABERS performance where relevant.	2.4.3, 2.5.3, 3.2	☐
31	Engage with Cleaning and Security Staff and instruct where appropriate, to switch off lights and equipment after hours and to report any issues that might lead to energy and water wastage.	3	☐
HVAC System Maintenance			
32	Ensure efficiency & maintenance of Chiller System.	6.2	☐
33	Ensure efficiency & maintenance of Cooling Towers.	6.3	☐
34	Ensure efficiency & maintenance of AHU and VAV boxes.	6.4	☐
35	Ensure efficiency & maintenance of Boilers.	6.5	☐
36	Ensure efficiency & maintenance of Pumps.	6.6	☐
37	Ensure efficiency & maintenance of Fans.	6.7	☐
38	Ensure efficiency & maintenance of Humidification and Dehumidification.	6.8	☐

Task	Action	Section in Guide	
39	Ensure efficiency & maintenance of Packaged HVAC Systems.	6.9	
40	Ensure performance & maintenance of Power Factor Correction system.	6.10	
41	Ensure optimised operation of BMS.	6.11	
42	Assess the need for Commissioning & Tuning.	6.12	
Further Opportunities			
43	Assess building Air Tightness & Thermal Insulation.	n/a	
44	Carry out Thermographic (infra-red) survey of Building Fabric, including Roof, to check for Heat Leakage.	n/a	
45	Ensure lighting upgrades achieve energy efficiency. Avoid lamps that give a high heat output, including Dichroic type lamps.	n/a	
46	Install efficient Lighting Control Systems.	n/a	

APPENDIX D: CHECKLIST – BUILDING OCCUPANT/ TENANT

Task	Action	Section in Guide	
1	Be aware of any obligations under tenancy agreements including Green Lease schedules.	1.5, 2.2	☐
2	If Building User Guide is available, ensure that staff are familiar with contents and responsibilities.	4.1, 4.4	☐
3	If a Building User Guide is not available, develop one in conjunction with the Facilities Manager.	4.4	☐
4	Ensure new purchases of office equipment comply with current Energy-Star standards. Enable automatic energy saving features such as hibernation.	3.3	☐
5	Advise Facilities Manager before carrying out any fit-outs and/or altering any systems that could affect the operation of the base building HVAC Systems. Ensure all work carried out complies with Tenancy Fit-Out Guidelines.	4.5	☐
6	Using utility metering (or sub-metering) monitor the tenancy energy consumption on a monthly basis. Develop benchmarks and KPIs. If time of use metering is installed, analyse the consumption and investigate unusual consumption patterns, after hours and during working hours. If necessary, carry out an Energy Audit.	2.4.3	☐
7	Review tenancy HVAC System Temperature Set-Points with the Facilities Manager. Ensure any Supplementary HVAC Systems installed do not counteract with the Central System.	3.3, 6.11	☐
8	Install Automatic Controls to minimise operation of Supplementary HVAC Systems.	6.11	☐
9	Inspect tenancy for un-authorised appliances such as Electric Heaters, Portable Air Conditioners and in-efficient Catering equipment. Investigate and Remove where appropriate.	3.3	☐
10	Discuss with the Facilities Manager possible opportunities for enhancing the efficiency of Office Lighting and Lighting Control Systems.	3.3	☐
11	Review the use of tenancy Window Blinds.	3.3	☐
12	Review the use of After-Hours HVAC	3.3	☐
13	Engage with Cleaning and Security Staff and instruct where appropriate, to switch off lights and equipment after hours and to report any issues that might lead to energy and water wastage.	3.3	☐

APPENDIX E: CHECKLIST – MAINTENANCE SERVICE PROVIDER

Task	Action	Section in Guide	
1.0	**HVAC Energy Efficiency Maintenance Implementation.**		
Policies and Maintenance Contract			
1	Obtain details of the Maintenance and Environment Policies from the Facilities Manager. Ensure these objectives are met.	1.5, 2	☐
2	Make recommendations regarding Scheduled Maintenance Frequencies, should deficiencies be detected.	2	☐
Resources			
3	Ensure suitably trained/qualified Maintenance Personnel are utilised to meet the Contract Requirements, including supervision.	2	☐
4	Ensure that suitable Communication Methods are in place.	2,3	☐
Asset Register			
5	Advise the Facilities Manager of any inaccuracies. Continuously update the Asset Register.	4.6	☐
6	Identify energy and water saving opportunities and include EIR in Asset Register.	1.2, 1.5, 2.4, 2.5, 3.4, 4.6, 4.7	☐
1.1	**Building Infiltration, Insulation and Shading.**		
1	Check the Building Entrance Auto Doors (where installed) are operating satisfactorily and are not open unnecessarily and for excessive periods of time.	n/a	☐
2	Inspect External Doors for gaps/leaking Door Seals that allow Infiltration.	n/a	☐
3	Inspect the condition of Windows, Frames and Seals.	n/a	☐
4	Inspect for Doors left open or forced open unnecessarily.	n/a	☐
5	Inspect for Ceiling Tiles to be in place and in good condition with no Air Gaps.	n/a	☐
6	Inspect inside Ceilings for Displaced Thermal Insulation.	n/a	☐
7	Inspect the condition and adequacy of the building Roof Insulation.	n/a	☐
8	Inspect for perimeter Air Leakage e.g. at Service Penetrations.	n/a	☐
9	Inspect floor-wall-ceiling joints for Air Gaps.	n/a	☐
10	Inspect Window Shading Devices and their operation.	n/a	☐
11	Consider installing Shading Devices, including Window Tinting to W and N facades.	n/a	☐
12	Consider installation of Automatic Window Blinds.	n/a	☐
13	Investigate feasibility of Painting the roof with a Solar Reflective Paint.	n/a	☐

Task	Action	Section in Guide	
14	Carry out Thermographic (infra-red) survey of Building Fabric, including Roof, to check for Heat Leakage.	n/a	
1.2	**Chiller**		
1	Ensure Logbooks are in place and up to date.	4.3	
2	Ensure Maintenance Schedules comply with Manufacturers' Recommendations and AIRAH DA19.	6.2	
3	Periodically clean Heat Exchangers.	6.2	
4	Carry out Performance Based Maintenance where applicable.	6.2	
5	Replace Thermostatic Expansion Valves with electronic expansion valves.	6.2	
6	Check Refrigerant Charge regularly.	6.2	
7	Repair Water Leaks promptly.	6.2	
8	Ensure Control Strategies are in place to maximise chiller system efficiency – Chilled Water and Condenser Water Reset.	6.2	
9	Optimise Chiller Sequencing Strategy.	6.2	
10	Ensure chiller Control Sensors are calibrated. Update the Calibration Information in the Log Book.	6.2	
11	Ensure Control Strategies are in place to minimise spurious chiller system operation – Outside Temperature Lock-Out and Cooling Call verification.	6.2	
12	Check that chiller unit is not oversized for Low Load Operation, especially after hours.	6.2	
13	Inspect chiller and associated Pipe Work Insulation for thickness and for signs of deterioration.	6.2	
14	Install BMS Interface to chiller controls for Monitoring Purposes	6.2, 6.11	
15	Ensure KPIs are in place with the necessary sub-metering to Monitor Performance of chilled water system.	2.4, 6.11	
16	Utilise BMS to Monitor Performance of chiller including COP, condenser and evaporator pressure drops and temperature approaches.	6.11	
17	Consider Replacing Obsolete Chillers with new efficient chillers. Optimise selection of new chillers, don't replace like for like. Consider Variable Flow Systems.	6.2	
1.4	**Cooling Towers**		
1	Ensure Logbooks are in place and up to date.	4.3	
2	Ensure Maintenance Schedules comply with manufacturers' recommendations and AIRAH DA19.	6.3	
3	Check for water wastage through Leakage and Splash.	6.3	
4	Check visually for signs of Leakage or Overflow when towers are in operation and when idle.	6.3	
5	Review specialist Water Treatment Contract and maintenance procedures. Ensure TDS controls are set up properly to optimise Bleed rate.	6.3	

Task	Action	Section in Guide	
6	Maintain Fill Material in clean condition.	6.3	
7	Ensure Airflow to cooling tower is not restricted.	6.3	
8	Check Drift Eliminators are fitted and in good condition.	6.3	
9	Ensure Control Strategies are in place to optimise cooling tower Staging and minimise fan energy consumption. E.g. wet bulb tracking.	6.3	
10	Install VSD control to Cooling Tower Fans.	6.3	
11	Check operation of cooling tower Bypass Valve.	6.3	
12	Check that pressure drop through cooling tower heat exchanger (where installed) is not excessive.	6.3	
13	Ensure KPIs are in place with the necessary Sub-Metering to Monitor Performance of cooling tower system.	6.3	
14	Replace Obsolete Equipment with modern energy and water efficient units.	6.3	
15	Consider the recovery of Bleed Water for purposes such as Irrigation or Flushing Toilets.	6.3	
16	Ensure water sub-meters are installed for Monitoring Consumption. Monitor through BMS if installed, with Alarm Functions.	6.3, 6.11	
17	Consider Monitoring Performance of cooling towers through BMS.	6.11	
18	When replacing Obsolete Equipment, consider options such as Adiabatic Coolers and for large installations, using Sea or River water.	6.3	
19	Consider alternative water sources such as Rainwater or Reclaimed Condensate from AHUs.	6.3	
1.5	**Air Handling Units and VAV Boxes**		
1	Ensure Logbooks are in place and up to date.	4.3	
2	Ensure Maintenance Schedules comply with Manufacturer's Recommendations and AIRAH DA19.	6.4	
3	Ensure Heat Exchangers are clean.	6.4	
4	Ensure Air Filters are clean.	6.4	
5	Check Air Filter efficiency for excessive Pressure Drop. E.g. > F5 grade?	6.4	
6	Check whether installed duct Noise Attenuators are really necessary.	6.4	
7	Check for Leaking Control Valves causing possible simultaneous heating and cooling.	6.4	
8	Ensure that there is no Air Leakage from ducts and access doors.	6.4	
9	Check AHU and ductwork for deterioration of Thermal Insulation.	6.4	
10	Check accuracy and location of zone Temperature Sensors.	6.4	
11	Check supply and return air paths for Restrictions, especially after office fit-outs.	6.4	

Task	Action	Section in Guide	
12	Ensure correct operation of Economy Cycle.	6.4	
13	Replace inefficient Motors.	6.4	
14	Align belts and pulleys.	6.4	
15	Where possible, replace V belts with Toothed Flat Belts that are more efficient. Consider effects of DOL starting.	6.4	
16	Minimise wasteful operation of active De-Humidification and Humidification.	6.4	
17	Check that there is minimal Throttling on ductwork Index Run. Carry out belt and pulley change where possible.	6.4	
18	Install VSDs where appropriate, to maintain constant volume (against variable pressure), constant pressure (against variable volume) or preferably Variable Volume and Variable Pressure for most energy saving.	6.4	
19	Replace variable Inlet Guide Vane fan volume control systems with VSDs.	6.4	
20	Ensure Service Lights inside AHUs are switched off.	6.4	
21	Where BMS is installed, set-up Trends on BMS to verify efficient operation of VSDs, Economy Cycle damper operation and checks for Leaking Valves.	6.4	
22	Ensure correct interaction between VAV boxes and AHU. Set up Diagnostic Screens to monitor correct performance of VAV boxes.	6.4	
23	Re-adjust Minimum and Maximum Air Flow Rates on VAV boxes to minimise over cooling and re-heat.	6.4	
24	Ensure zone set points are not altered in an ad-hoc manner in an attempt to 'fix' underlying problems.	6.4	
25	Set up smart control strategies such as Critical Zone Reset where appropriate.	6.4	
26	Use BMS to maximum potential to set-up Trends that identify poor performance.	6.4, 6.11	
27	Re-balance and Re-commission the system if necessary.	6.4	
28	Replace systems that are at end of life with modern energy efficient units.	6.4	
29	Investigate possibility of Recovering Heat from exhaust air, where this is cost effective.	n/a	
1.6	**Boilers and Heating Systems**		
1	Ensure Logbooks are in place and up to date.	4.3	
2	Ensure Maintenance Schedules comply with manufacturers' recommendations and AIRAH DA19.	6.5	
3	Service boilers periodically, including performing Combustion Analysis.	6.5	
4	Ensure Water Treatment is satisfactory.	6.5	
5	Repair Water Leaks promptly.	6.5	
6	Check condition of Thermal Insulation on heating pipework system including components such as valves and strainers. Repair where necessary. Install thermal insulation over Pipeline Components.	6.5	

Task	Action	Section in Guide	
7	Ensure control strategies are in place to minimise spurious boiler system operation. E.g. Outside Temperature Lock-Out and Heating Call verification.	6.5	
8	Optimise Boiler Sequencing strategy.	6.5	
9	Check that boilers are not oversized for Low Load Operation.	6.5	
10	Isolate off-line boilers where appropriate.	6.5	
11	Ensure control strategies are in place to maximise boiler and system efficiency. E.g. heating temperature re-set (whilst avoiding back end corrosion).	6.5	
12	Where BMS is installed set Trends, Targets and Alarms on energy consumed, flow and return temperatures etc.	6.5	
13	Replace boiler with more energy efficient type. E.g. Condensing Boiler.	6.5	
14	Consider the feasibility of a flue gas recovery/economiser system.	n/a	
1.7	**Pumps and Distribution Systems**		
1	Ensure Maintenance Schedules comply with manufacturers' recommendations and AIRAH DA19.	6.6	
2	Routinely check for Water Leaks from pipework and components.	6.6	
3	Ensure non-essential pumps are switched off.	6.6	
4	Clean or Flush Strainers periodically.	6.6	
5	Investigate whether pumps are Throttled at Index Run. Resize Impellor or install VSD where appropriate.	6.6	
6	Consider converting constant flow systems with 3 port valves to variable flow systems with 2 port valves, with Flow Modulation through VSDs.	6.6	
7	Consider conversion of constant volume systems to Variable Volume primary/secondary systems, using VSDs to save energy.	6.6	
8	Size pump motors correctly to Avoid Under-Sizing (could lead to premature failure) and Avoid Over-Sizing (potentially in-efficient).	6.6	
9	Do not re-wind motors that operate for long hours, typically more than 100 hours per year, if the re-wound efficiency is lower. Have a Replacement Policy that specifies High Efficiency Motors.	6.6	
10	Where VSDs are installed for control purposes, set up Trends on BMS or VSD and ensure that the system modulates.	6.6, 6.11	
1.8	**Fans**		
1	Ensure Maintenance Schedules comply with manufacturers' recommendations and AIRAH DA19.	6.7	
2	Routinely check for Air Leaks from ductwork and components.	6.7	
3	Ensure non-essential fans are switched off.	6.7	
4	Investigate whether fans are Throttled at Index Run. Carry out belt and pulley ratio change or install VSD where appropriate.	6.7	

Task	Action	Section in Guide	
5	Consider conversion of constant volume systems to Variable Volume Systems, using VSDs to save energy.	6.7	
6	Replace Variable Inlet Guide Vane fan volume control systems with VSDs.	6.7	
7	Do not re-wind motors that operate for long hours, typically more than 100 hours per year, if the re-wound efficiency is lower. Have a Replacement Policy that specifies High Efficiency Motors.	6.7	
8	Size fan motors correctly to Avoid Under Sizing (could lead to premature failure) and Avoid Over Sizing (potentially inefficient).	6.7	
9	Install High Efficiency Fans that incorporate EC (electronically commutated) motors where appropriate.	6.7	
10	Where VSDs are installed for control purposes, set-up Trends on BMS or VSD and investigate whether System Modulates.	6.7, 6.11	
1.9	**Humidification and Dehumidification**		
1	Ensure Maintenance Schedules comply with manufacturers' recommendations and AIRAH DA19.	6.8	
2	Investigate whether Humidification and active De-Humidification exists. Report to Facilities Manager.	6.8	
3	Log operation of humidification and active de-humidification, preferably through BMS.	6.8	
4	Ensure humidity sensors are Calibrated.	6.8	
5	Maximise use of Economy Cycle, to minimise active humidification and de-humidification.	6.8	
6	Ensure building fabric is Well Sealed to prevent moisture loss or gain.	6.8	
2.0	**Packaged HVAC Systems**		
1	Ensure Maintenance Schedules comply with manufacturers' recommendations and AIRAH DA19. Ensure correct Refrigeration Charge is maintained.	6.9	
2	Clean or replace Air Filters regularly.	6.9	
3	Maintain Heat Exchangers (Coils) in a clean state.	6.9	
4	Where Economy Cycle is installed, check for correct operation.	6.9	
5	Where economy cycle is not installed, either install economy cycle or ensure Outside Air/Re-Circulation dampers are set up properly.	6.9	
6	Minimise operation of units, based on Time Schedules and temperature Set Points.	6.9	
7	Interlock controls to ensure that tenant installed systems Do Not Counteract base building systems.	6.9	
8	For systems with long operating hours, typically 1000 hours/year, install units that have high efficiency, preferably in excess of current MEPS.	6.9	
8	For packaged HVAC units that use the condenser water loop for heat rejection, ensure motorised valves are installed to Automatically Shut Down the condenser water flow when the compressor is not running.	6.9	

Task	Action	Section in Guide	
2.1	**Power Factor Correction**		
1	Ensure power factor correction equipment is operating correctly, and the power factor is ideally above 0.98, or at least, >0.95.	6.10	
2	Monitor the power factor through the BMS.	6.10	
2.2	**BMS and Controls**		
1	Ensure documentation for BMS and Control Strategies are available and understood.	4	
2	Ensure protocols for making changes to parameters that affect HVAC systems are agreed with Facilities Manager. Ensure all changes are Documented. Agree acceptable level of Password Access, for Facilities Management staff, Maintenance Contractor's staff, and BMS Specialist Staff.	6.11	
3	Ensure skilled BMS staff are available.	6.11	
4	Ensure Maintenance Schedules comply with manufacturers' recommendations and AIRAH DA19.	6.11	
5	Ensure control sensors have been Calibrated and field items have been checked for correct operation.	6.11	
6	Utilise control strategies to improve HVAC System energy efficiency.	6.11	
7	Utilise the BMS to monitor energy consumed, set trends, KPIs and targets for implementation.	2.4.3, 6.11	

APPENDIX F: CHECKLIST – ENERGY AND MAINTENANCE AUDITOR

Task	Action	Section in Guide	
1	Review environmental and maintenance policies, are they current?	2.2, 2.3	☐
2	Compare performance Benchmarks for building.	2.4.3	☐
3	Review energy and water Metering Systems and recording systems.	2.5.3	☐
4	Review building KPIs.	2.4.3	☐
5	Carry out an Energy Audit in accordance with AS/NZS 3598.	2.5	☐
6	Review documentation:	4	☐
	O&M manuals, Commissioning Data, As installed Drawings	4.2	☐
	Maintenance Log Books, Service Callouts and Reports	4.3	☐
	Building User Guide	4.4	☐
	Tenancy Fit-out Guide	4.5	☐
	Asset Register	4.6	☐
7	Review building Operational Practices. Walk through tenancies.	3	☐
8	Inspect condition of Building Fabric including façade, solar shading and air tightness.	3	☐
9	Review condition, maintenance regime and operation of Chiller. Inspect chiller log book.	6.2	☐
10	Review refrigerant storage, handling and Recording Procedures.	6.2	☐
11	Review condition, maintenance regime and operation of Cooling Towers. Inspect cooling tower log book.	6.3	☐
12	Review condition, maintenance regime and operation of AHUs and VAV boxes.	6.4	☐
13	Review condition and maintenance regime of Ductwork, associated components and insulation.	6.4	☐
14	Review condition, maintenance regime and operation of Boilers. Inspect boiler log book.	6.5	☐
15	Review condition, maintenance regime and operation of Pumps.	6.6	☐
16	Review condition, maintenance regime and operation of Fans and supply/extract systems including car park ventilation system.	6.7	☐
17	Review condition, maintenance regime and operation of Humidifiers and Active De-Humidification. Comment on the necessity for such systems.	6.8	☐
18	Review condition, maintenance regime and operation of packaged HVAC systems. Comment on controls and the possibility of tenant installed systems Counteracting the central systems.	6.9	☐
19	Review operation of Power Factor Correction system and any issues that may contribute to the maximum demand of the building.	6.10	☐
20	Review condition, maintenance regime and operation of BMS and the associated field items.	6.11	☐
21	Comment on the effectiveness of the BMS being used as a tool for Monitoring the efficiency of HVAC systems.	6.11	☐

APPENDIX G: CHECKLIST – CONTROLS SPECIALIST

Task	Action	Section in Guide	
1	Review the overall capability of the BMS and effectiveness of its utilisation with regards to delivering the control, monitoring, reporting and diagnostic functions required by the buildings environmental performance objectives.	1,6	☐
2	Agree with Facilities Manager and other key Stakeholders, any Change Management protocols, with regards to altering operational set points and control strategies.	6	☐
3	Review current maintenance practices for BMS in line with Maintenance Schedules as required in (AIRAH DA19) and to manufacturer's recommendations.	6	☐
4	Ensure a BMS Logbook is in place and kept up to date with regards to change documentation.	6	☐
5	Ensure control sensors have been Calibrated and field items are operational.	6	☐
6	Where temperature sensors are mounted on external walls, check the quality of cable gland sealing, to ensure air Does Not Leak past sensor and affect its reading. Ensure that the sensor mounting plate is Thermally Insulated to avoid false readings.	6	☐
7	Ensure that zone sensors are located in Representative Locations. Check that temperature sensors are not affected by external factors such as Heat Gains from office equipment.	6	☐
8	Check for Excessive Operation of HVAC systems, such as central systems being operated to serve a small area.	6	☐
9	Review BMS capability for detection of failures, non-performance of equipment and non-achievement of KPIs. Check that Alarms are set on the BMS with satisfactory communication methods for Exception Reporting.	6	☐
10	Check that controls have not been over-ridden for a short-term purpose and not reset afterwards.	6	☐
11	Check that Time Scheduling is accurate including the programming of local public holidays.	6	☐
12	Check that ad-hoc adjustments have not been made to zone temperature sensors, in an attempt to 'quick fix' complaints.	6	☐
13	Check that ancillary equipment do not operate unnecessarily, after hours when main plant is not in operation.	6	☐
14	Check for Simultaneous Operation of conflicting items of plant. E.g. leaking hot water and chilled water valves. Where possible set up automatic Alarm Functions.	6	☐
15	Ensure temperature control set points are not over conservative. E.g. can the heating and cooling requirements for areas such as entrance lobbies be set-back?	6	☐
16	Ensure pressure control set points on VSDs are not too high, where possible use Smart Control Strategies including critical zone reset.	6	☐
17	Where VSDs are installed in variable volume and/or pressure systems, ensure trending is set up to Monitor that the systems are Modulating rather than operating at fixed speed.	6	☐
18	Enable optimum start/stop.	6	☐
19	Programme night purge, where appropriate.	6	☐
20	Programme flow temperature re-set and outside temperature lock-out for heating system.	6	☐

Task	Action	Section in Guide	
21	Programme chilled water and condenser water flow temperature re-set and outside temperature lock-out for cooling system.	6	☐
22	Ensure that Economy Cycle operates correctly, set up a trend to monitor its operation.	6	☐
23	Utilise the BMS to monitor energy consumed, set trends, KPIs and targets for implementation:	2.4.3. 6	
	Chiller unit COP monitoring		☐
	HVAC energy consumption		☐
	Cooling tower water consumption		☐
	Monitoring and targeting of energy consumption.		☐

APPENDIX H: CHECKLIST – DESIGN ENGINEER

Task	Action	Section in Guide	
General			
1	Establish the required building environmental performance targets. Carry out Building Simulations and optimise design solutions that would deliver the design targets.	n/a	☐
2	Consider all options available including mixed mode ventilation, VAV (conventional and low temperature), chilled beams and displacement ventilation.	n/a	☐
3	Maximise passive means to reduce HVAC operation. E.g. use economy cycle to full potential and consider water side economisers where viable. Consider solar shading of the façade, specify blinds and their controls as part of the base building package – don't leave this aspect for Building Occupants. Ensure that a 'cool roof' that reflects solar energy is specified. Eliminate (or minimise) the need for active humidification and de-humidification. Consider heat recovery.	n/a	☐
4	Detail and specify the degree of air tightness required from the building, especially on buildings that have chilled beams.	n/a	☐
5	Consider part load performance, taking into account interaction of equipment under part load conditions. E.g. heating systems counteracting cooling systems. Give priority to energy efficiency when considering key equipment such as chillers, boilers and AHUs.	n/a	☐
6	To serve small after-hours loads such as lift motor rooms and computer rooms, Specify separate equipment rather than operating central plant inefficiently.	n/a	☐
7	Ensure Tenant systems such as supplementary condenser water, tempered fresh air supply and exhaust air have motorised valves and actuators that shut down when these systems are not operating. Control the connected base building plant via VSDs. Ensure car park ventilation systems have CO based control.	n/a	☐
8	Do not over complicate HVAC systems. Always consider commission – ability and maintainability of HVAC systems and user friendliness.	n/a	☐
9	Clearly state the design intent and mode of operation of energy & water saving features.	n/a	☐
10	Ensure energy and water sub-metering is specified.	n/a	☐
11	Ensure that the required project documentation is specified and is actually delivered by the Contractor before hand over. Operating and maintenance manuals, as fitted drawings, commissioning figures, maintenance log books, building users guide and tenancy guidelines for fit-out and operation are important for efficient maintenance and operation.	n/a	☐
12	Ensure that project commissioning, fine tuning, monitoring and verification of the HVAC services and their KPIs are specified. Specify the services and detail the scope of work from an Independent Commissioning Agent.	n/a	☐
HVAC SYSTEMS			
13	Minimise wasteful plant operation, ensure local public holidays are scheduled, specify optimum start and stop, limit after hours operation to no more than one hour per request.	6.11	☐
14	Ensure adequate motorised branch duct dampers are installed to prevent after hours HVAC operation in un-occupied zones.	6.4	☐
15	Ensure adequate sub metering is installed in line with Green Star requirements, NABERS requirements and for monitoring KPIs. Ensure meters are connected to BMS, the readings are recorded, trended and archived. To assist the Facilities Managers, consider specifying trend analysis software and exception reports.	2.4.3, 2.5.3.	☐

Task	Action	Section in Guide	
16	Specify diagnostic screens to enable tracing of faults. Screens should be set up for chilled water system, condenser water system, hot water system, and for each AHU including the VAV boxes it serves. Screens should display key information including heating/cooling calls, equipment staging and key control parameters and control logic.	6.11	
17	Specify control interfaces to Tenant installed equipment to ensure that these systems cannot counteract the central systems.	6.9, 6.11	
18	For the control of fan coils, use room sensors instead of return air sensors.	6.9, 6.11	
19	Specify adequate sensors for performance monitoring of HVAC systems. Include air filter differential pressure, pressure and temperature drops across chiller condensers and evaporators. The installation of sensors after heating and cooling coils can also detect leaking valves and energy wastage.	6.11	
20	Don't over-specify tight temperature control bands. Specify 1–1.5ºC dead zone between heating 'off' and cooling 'on' in occupied areas.	6.11	
21	Don't over-specify tight temperature control bands for areas such as entrance lobbies used for transient occupancy. Typically, the temperature within such areas can be allowed to 'float' between 17ºC and 27º without complaints and adverse effects to occupied areas.	6.11	
22	Specify correct installation of sensors and their calibration. Where sensors are mounted on external cavity walls, ensure gland seals are installed to prevent air leakage into sensor enclosures and thermal insulation is applied behind the sensor.	6.11	
Chiller			
23	Specify chillers that have high COPs and IPLVs, in accordance with the expected duty cycles.	6.2	
24	Apply whole of life costing – consider water cooled, adiabatic and air cooled options.	6.2, 5	
25	Consider variable volume chilled water pumping, including the possibility of using chillers in series-counter flow configuration.	6.2	
26	Consider chilled water re-set and condenser water reset.	6.2	
27	Ensure that chillers are sequenced correctly to deliver the most efficient output for the prevailing chiller demand. Stage chillers up/down based on current (A) draw of compressors rather than kWr.	6.2	
28	Minimise spurious cooling demand calls – specify an ambient low temperature lock-out and give consideration to cooling calls – avoid the possibility of a faulty motorised valve or broken VAV box causing a cooling call.	6.2, 6.11	
29	Specify electricity sub-metering and chiller thermal metering to enable monitoring chiller performance and KPIs.	2.5.3	
30	Specify high level interface with BMS.	6.2, 6.11	
Boiler			
31	Specify boilers that have high efficiencies. Use condensing boilers as the lead boiler where appropriate.	6.5	
32	Minimise heating calls – specify an ambient high temperature lock-out and give consideration to verifying heating calls – avoid the possibility of a faulty motorised valve or broken VAV box causing a heating call.	6.5, 6.11	

Task	Action	Section in Guide	
Cooling Tower			
33	Optimise selection, combine base building and Tenants supplementary cooling towers together to obtain the lowest approach temperature possible with minimum consumption of fan power.	6.3	☐
34	Specify a fan sequencing strategy that simultaneously operates all fans in parallel, rather than ramping individual fans to 100% before staging the next fan.	6.3	☐
35	Specify wet bulb tracking system that uses at least two ambient dry bulb/wet bulb sensors.	6.3, 6.11	☐
36	Install water metering connected to BMS. Set up KPIs and alarm functions to report abnormally high and low water consumption.	6.3, 6.11	☐
37	Install automatic bleed through a TDS system. Monitor the system through BMS.	6.3, 6.11	☐
AHU			
38	Specify low pressure drops on the air and water side.	6.4	☐
39	Oversize heat exchangers where appropriate, to get the most efficiency from chillers (higher chilled water temperatures) and boilers (lower heating water temperatures using condensing boilers) where feasible.	6.4	☐
40	When considering zoning, take into account orientation, variances in heat loads and after-hours plant requests.	6.4	☐
41	Minimise the need for active de-humidification and humidification.	6.4,6.8	☐
42	Use the economy cycle to maximum potential, in humid areas sense enthalpy of air rather than dry bulb temperature. Use two enthalpy sensors to check for sensors drifting out of calibration.	6.4	☐
43	Control outside air based on CO_2 sensing, especially important for variable occupancy areas.	6.4	☐
44	Specify critical zone re-set for the control of AHU fans rather than using a fixed static pressure.	6.4	☐
45	Avoid using hi/low select signal from zone sensors for AHU control zone purposes, the hi/low select signal could be originating from a zone served by a faulty VAV box. Use a verification system or an averaging system to reduce the possibility of a faulty VAV box affecting the operation of the entire AHU.	6.4	☐
46	Use night purge when suitable outdoor conditions exist, use enthalpy sensing in humid climates. Excessive use of night purge (>2 hours) can be counterproductive. Disable heating system for a set period (e.g. 2 hours) after night purge ceases.	6.4	☐