Manual

E-MAN-STD-001

Energy Efficiency

Document number: MAN-00391

Ver no.	Description	Owner		Approved for issue		
		Position	**Approval**	**Position**	**Approval**	**Date**
1	Initial issue	Principal Energy Advisor	See supporting information in REX	Manager DTI Performance	See supporting information in REX	08/12/2022
This Engineering Standard was endorsed by RPEQs on behalf of Seqwater:						

SOURCE STORE SUPPLY

Version History

Ver	Date	Description	Author	SME	Owner	Approver
1	2/11/2022	Initial Issue				

(Refer Controlled Document in REX for Author, SME, Owner and Approver details)

Contents

1 Introduction

1.1 Background and Context

Seqwater owns and operates 26 dams, 34 Water Treatment Plants, three Advanced Water Treatment Plants and one desalination plant. These assets collectively consume almost 140 GWh of energy annually at a cost of approximately $22 million. With an increasing reliance on climate-resilient assets, such as the Gold Coast Desalination Plant and Western Corridor Recycled Water Scheme, Seqwater's energy consumption is forecast to double by 2030.

In response to these growing energy demands, Seqwater developed a Corporate Energy Strategy to establish a vision for the organisation's prudential energy management. This strategy introduces three overarching energy strategic objectives, as outlined below.

Objective 1	Objective 2	Objective 3
Support the achievement of sustainability targets	**Ensure energy security**	**Use energy more efficiently**
Support the achievement of Seqwater's net-zero carbon target and other sustainability and compliance targets	Ensure energy security to support water supply certainty	Implement energy efficiency initiatives to reduce energy consumption and costs.

Figure 1-1 Corporate Energy Strategy objectives

To complement the Corporate Energy Strategy and realise these three objectives, additional guidance and support has been developed to support project decision-making.

1.2 Purpose

This Energy Efficiency Manual (EEM) has been developed to assist project managers and other decision-makers to consider energy efficiency when upgrading, planning, or developing Seqwater infrastructure[1].

Each of the asset classes and equipment types referenced in this EEM are well represented across Seqwater's infrastructure portfolio. A breakdown of the EEM's intended approach, roles and responsibilities, and whole of life (WOL) decision methodology is outlined in Section 2.

[1] Energy efficiency is only one of several factors impacting the design and intended operation of Seqwater's physical assets. Competing requirements such as water quality, water demand (i.e. service levels) and safety must also be considered and will take precedence over energy efficiency.

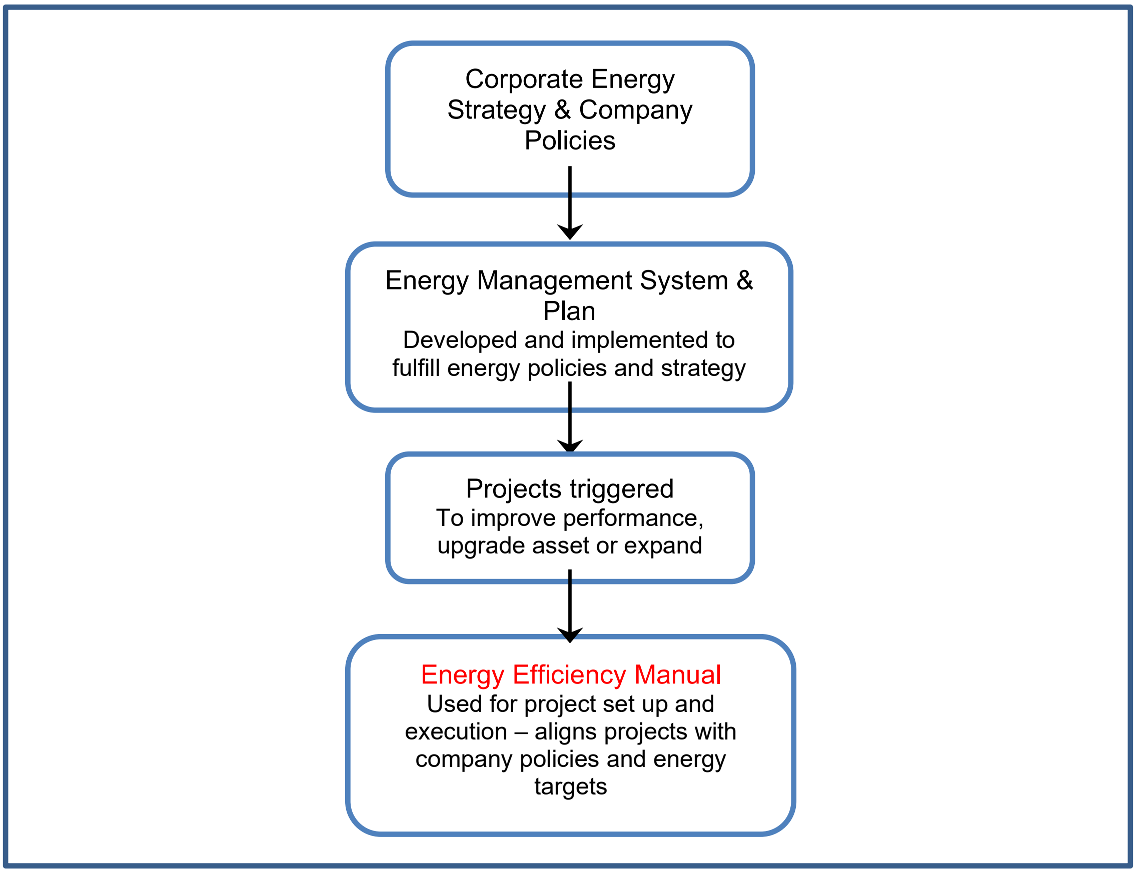


Figure 1-2 EEM context diagram

2 Governance

2.1 Introduction

Energy awareness can be effectively governed within an organisation by integrating energy efficiency into existing processes and systems. This approach to governance needs to transcend roles, titles, and individuals that will invariably change over time. Therefore, the aim is to link appropriate governance measures with the underlying processes and decision-making that will ultimately drive energy efficient outcomes.

With the understanding developed through a course of interviews with key stakeholders, it was determined that the core process for Seqwater to influence energy efficiency is the Gateway Process. This process guides the consideration of all improvement opportunities and therefore has a range of associated procedures and checklists (i.e., gates) that need to be 'opened' for the opportunity to progress. The checklists presented in this EEM will be used to update the strategic needs analysis and associated business case templates to ensure that appropriate energy considerations are made.

2.2 Approach

The EEM outlines Seqwater's approach to achieving energy efficient project outcomes during the upgrade, planning, development, and operation of Seqwater infrastructure. The EEM provides actions and deliverables for the design team for each project undertaken by Seqwater to maintain, enhance, or build new assets.

Energy efficiency decisions need to follow the processes and guidance outlined in this EEM including providing design options for evaluation by Seqwater. The Sustainability Engineer/Consultant and Quantity Surveyor on each project must provide key metrics of WOL cost and carbon as per the methodology below for the options presented by the design team. This allows Seqwater to consider energy efficiency and carbon in conjunction with capital expenditure for all decision making relating to assets.

Decisions concerning energy efficiency should be documented using the checklists contained within this manual. Where a process, guideline, or recommendation from the EEM is not met, projects should provide an explanation on why this has occurred.

2.3 Implementation Process

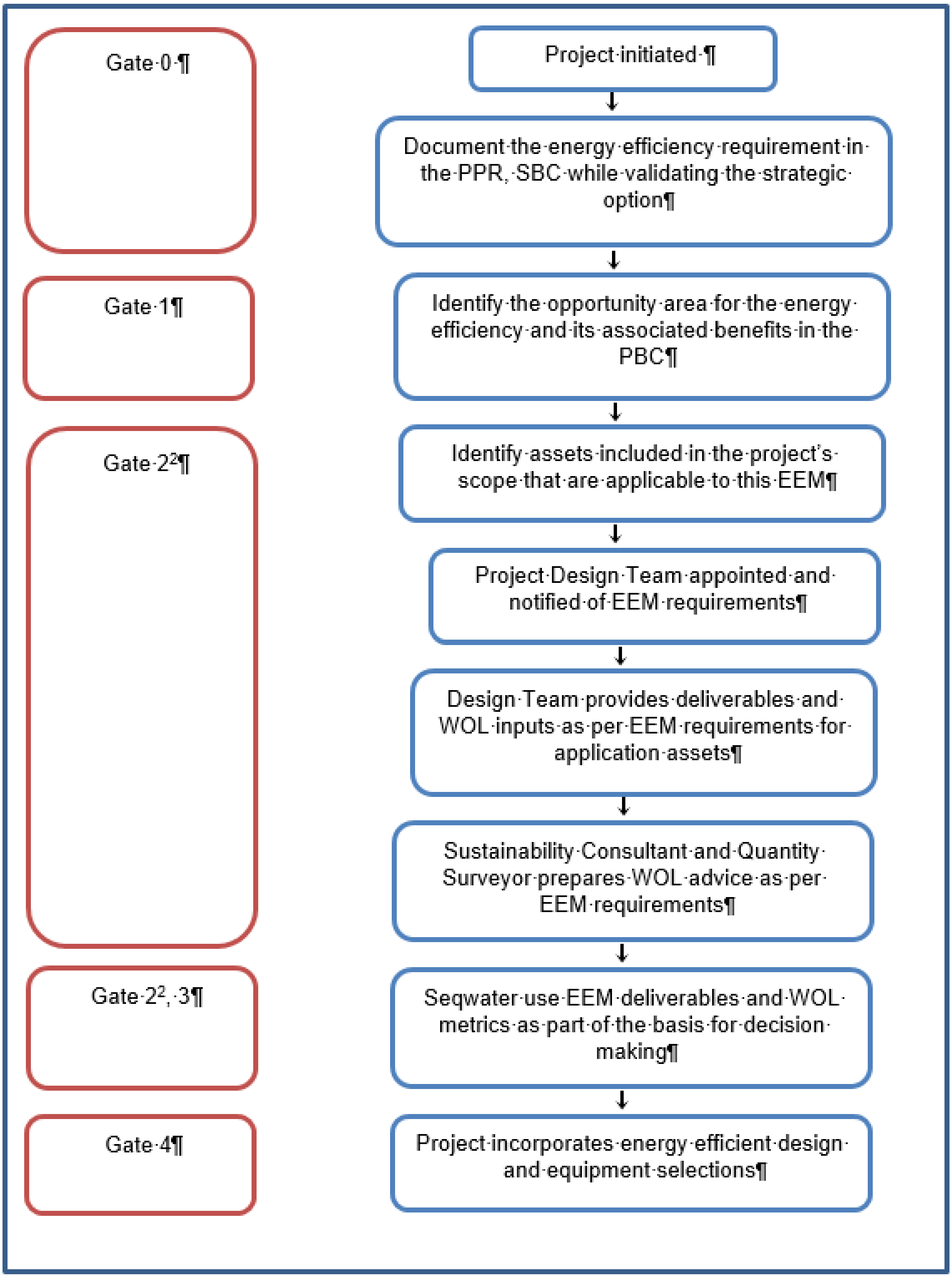


Figure 2-2-1 EEM implementation process

[2] These activities would form part of Gate 4 for a D&C contract.

2.4 Roles and Responsibilities

The following is a recommended set of roles and responsibilities for an energy efficiency project, but care needs to be taken to make the roles appropriate for the project.

Table 2-2-1 Roles and responsibilities for implementation of EEM

Role	Responsibilities
Seqwater Project Manager	• Appoint Design Team. • Provide Design Manager and Design Team with this EEM. • Decide amongst competing equipment or system options.
Design Manager	• Identify applicable assets within the project's scope that are to comply with this EEM. Advise design team of applicability. • Provide documentation during the design phase as outlined in this EEM. • Support Seqwater Project Manager to decide amongst competing equipment or system options.
Design Team	• Ensure that energy efficiency opportunities are adequately considered for relevant equipment or systems. • Assist in the preparation of documentation during the design phase as outlined in this EEM. • Provide input into WOL assessment.
Sustainability Consultant/Engineer	• Provide input into WOL assessment.
Quantity Surveyor	• Complete WOL assessment to support decision-making. • Ensure that the WOL assessment has been completed to the satisfaction of the Energy Unit (certification from the Energy Unit shall apply).
Energy Advisor	• Provide advice on the EEM • Ensure compliance and certification with the EEM • Ensure that the EEM is kept up to date

2.5 WOL Assessment

Seqwater uses a WOL assessment framework to support decision-making through the planning and design stage. A consistent approach is to be applied to all projects throughout the design process to assess the total cost of investment decisions by Seqwater.

WOL assessments should be undertaken in accordance with the requirements of AS/NZS 4536-1999 Life cycle costing – An application guide. Net Present Values (NPV) are to be calculated when undertaking WOL assessments. Final WOL calculations should be documented as part of the project's submission or contained as a separate WOL report. Figure 2-2 illustrates the key inputs, stages, and considerations when completing a WOL assessment.

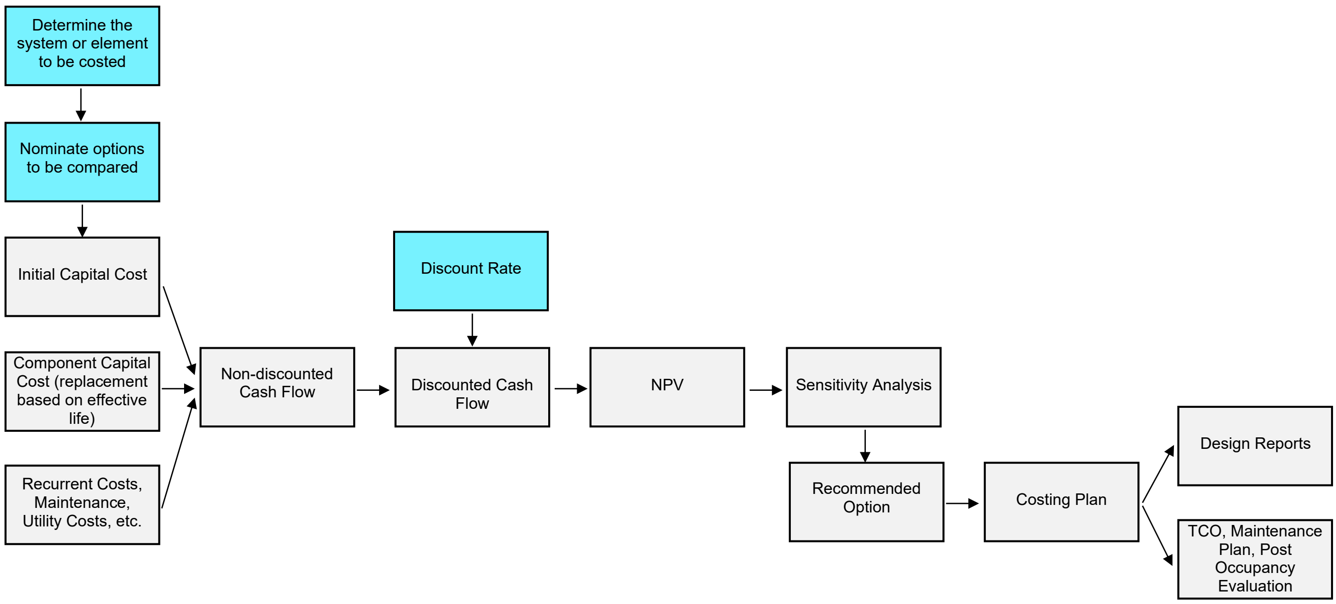


Figure 2-2-2 WOL Investigation Flowchart

2.6 Using WOL

Priority shall be given to projects that reduce operational costs and improve energy efficiency to the greatest extent. Where competing (i.e., mutually exclusive) equipment or system options arise, preference should be given to the option that is calculated to yield a higher NPV. Where this is not followed, justification shall be provided as part of the project documentation at the relevant project stage.

Project teams may wish to include a 'null' option (i.e., where the existing equipment or system is retained in its current form) as part of a broader WOL assessment. Comparing this 'null' option against competing equipment or system improvements may help to solidify and strengthen the project's underlying business case and ensure that Seqwater's capital is being allocated appropriately.

2.7 WOL Assumptions

Assumptions that are to be included in a WOL assessment:

- Assessment period
- Acquisition costs
- Replacement costs
- Maintenance costs
- The asset's useful life
- Annual operating costs (including any sewage/trade waste discharge costs)
- Creation of and resultant savings from Renewable Energy Certificates (REC) under the Renewable Energy Target (RET) or similar state-based schemes
- Discount rate and other escalation rates (e.g., maintenance, labour, capital components, etc.)
- Disposal costs, including salvage value at the end of the asset's forecast useful life

2.8 Default Discount and Escalation Rates

The default discount and escalation rates referenced in Table 2-2-2 are intended to serve as an example only. The project's Quantity Surveyor and/or other key personnel should derive specific values to support individual WOL assessments.

Table 2-2-2 Default discount and escalation rates for WOL calculations

NPV Criteria	Escalation Rate	Source
Discount Rate	3.97%	Average 10-year Australian Government Bond rate from Nov 2007 to Nov 2017
Electricity	3.5%	Median from several price projection studies
Gas	3.5%	Median from several price projection studies
Diesel	3.5%	Median from several price projection studies

2.9 Seqwater Decision Making Criteria

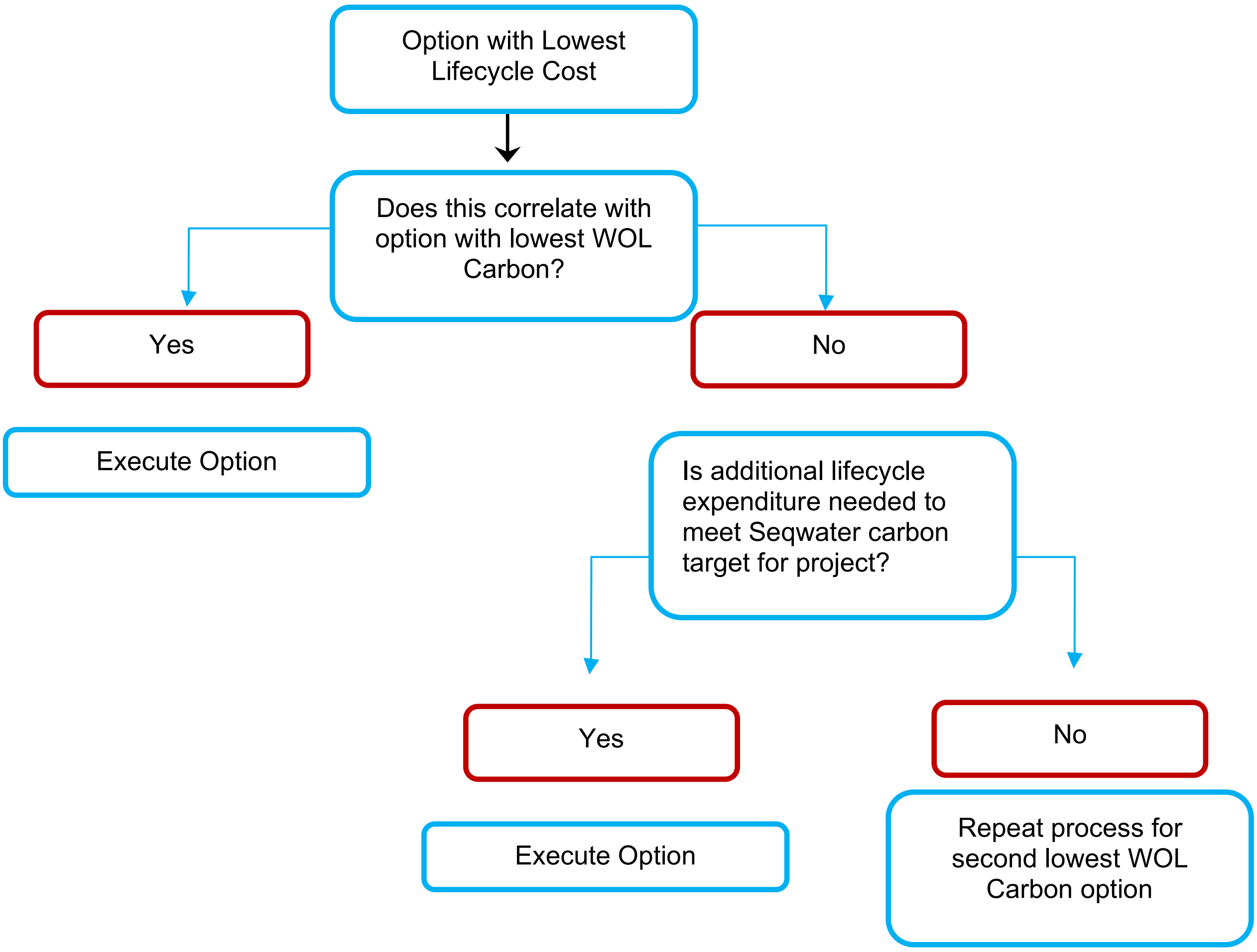


Figure 2-2-3 Seqwater decision-making criteria

3 Motors

3.1 Overview

A motor system includes the motor, coupling, drive and associated electrical infrastructure. Gearbox and belt driven type motors can have lower efficiencies, direct drive motors generally are more efficient.

3.2 Efficiency Considerations

The following table outlines the processes and considerations that should be followed to determine energy efficient outcomes at each project phase.

These must be implemented by the relevant discipline in the project Design Team, the Sustainability Engineer/Consultant, and the Quantity Surveyor.

Table 3-1 Energy efficiency considerations for motor systems

Project Phase	Consideration	Deliverable
Project Planning	Identify motor applications based on project scope and brief	☐ Detailed Business Case
Preliminary Design	• Define the relevant systems where there are opportunities to utilise high efficiency motors based on cost, annual power consumption, run time and motor size • WOL assessment	☐ Preliminary Design Report ☐ WOL Report
Detail Design	• Motor efficiency • Variable speed drives (VSDs)[3] • Energy management system	☐ Detail Design Report – Including section on energy efficiency
Tender	Assess Tender responses for energy efficiency implementation	☐ Tender Evaluations
Construction	• Installation as per design and manufacturer requirements • Review of commissioning results for correct operation	☐ Inspection Reports ☐ Commissioning Reports
Post Practical Completion	• Monitoring of system operation • Site tuning process to include review of motor performance • General maintenance	☐ Ongoing Maintenance Reports

[3] Refer to Section **Error! Reference source not found.** for information concerning variable speed drives.

3.3 Technical Details

The information presented in Table 3-2 expands on the energy efficiency considerations that are referenced in Table 3-1.

Table 3-2 Description of efficiency considerations for motor systems

Efficiency Consideration	Description
WOL assessment	• Perform a whole a life (WOL) assessment during the preliminary design stage detailing energy efficiency considerations and feasibility for the project specific requirements. The motor WOL assessment must include the following parameters as a minimum in the analysis: ○ Capital cost ○ Ongoing cost ○ Annual power consumption ○ Net payback period ○ Motor size ○ DOL/VSD ○ Load factor ○ Power factor ○ Duty % ○ Price of electricity ○ Price for demand ○ Tariff structure (peak/off-peak etc.) ○ Asset life ○ Operation & maintenance
Motor efficiency	• Selection of high efficiency motors leads to ongoing energy savings and reduced overall electrical loads. High efficiency motors generally have a higher initial capital cost for implementation. Selection of high efficiency motors should be evaluated in the project WOL cost benefit analysis. • Provide high efficiency motors for fixed and variable speed applications. • High efficiency motors should meet IEC “IE3” premium efficiency or better rating. • Specifications to include requirement for submission of manufacturers certification for each motor unit. • Provide a detailed analysis of the proposed motor types and technologies in the WOL report outlining the pros and cons of each option applicable to the project specific requirements.
Variable speed drives	• For variable speed applications, motors should incorporate variable speed drives for energy efficient operation with variable speed control to accurately match the desired system demand and for ramping start up to reduce starting current draw.
Energy management system	• Consider implementation of an energy management system integrated with a BMS to allow ongoing monitoring, data logging and fine tuning of selected plant operation.

3.4 Additional Materials

Table 3-3 includes references to additional technical documentation concerning motor systems.

Table 3-3 Supplementary materials supporting energy efficient motor systems

Related Energy Efficiency Consideration	Document Publisher (Link)	Relevance
Various	United Nations Climate Technology Centre & Network https://www.ctc-n.org/technologies/energy-efficient-motorshttps://www.ctc-n.org/technologies/energy-efficient-motors	The United Nations have published a comprehensive report concerning motor systems, their applications within industry, and the various interventions and design considerations that are available to improve their energy efficiency.
Various	National Center for Appropriate Technology https://www.ncat.org/energy/energy-toolkit/energy-efficient-motors/	The National Center for Appropriate Technology (NCAT) has developed an energy efficient motors toolkit. This toolkit outlines the fundamentals of motor systems, as well as efficiency measures to reduce a system's energy consumption.
Procurement	Equipment Energy Efficiency (E3) Program https://www.energyrating.gov.au/products/electric-motors	The Equipment Energy Efficiency (E3) program, jointly administered by the Australian and New Zealand Government's, has developed a landing page that hosts a variety of information concerning energy efficiency standards for motors, product databases, and other technical publications.
Various	United States Office of Energy Efficiency & Renewable Energy (EERE) https://www.energy.gov/eere/amo/motor-systems	The office of EERE have developed a comprehensive collection of fact sheets, case studies, and other technical publications regarding energy efficient motor systems.

3.5 Case Studies

3.5.1 Worked Example: End of Life Replacement for Motors

A textile manufacturing company is developing a new production line. It needs to install motors with a combined capacity of 2,750 kW. The motors will run approximately 8,000 hours per annum, with an average load of 75%. There are two options for replacement:

1.) Replace with standard efficiency motors that have an aggregate efficiency of 89.5% at 75%, or
2.) Replace with more expensive premium efficiency motors with an aggregate efficiency of 92.2% at 75% load.

To evaluate the suitability of each option, the company compares each system's expected useful life, acquisition cost, operation and maintenance costs, and electricity consumption.
Despite costing $50,000 more to acquire, the comparatively energy efficient motors ultimately present a more energy efficient and cost-efficient option over the useful life of the asset. The energy efficient motors are

estimated to consume significantly less electricity each year than the alternate systems, equating to a saving of more than $100,000 per annum.

Author/Publisher: NSW Office of Environment & Heritage
Source: Case study for financing a motor upgrade (nsw.gov.au)

3.5.2 Optimizing Electric Motor Systems at a Corporate Campus Facility

Minnesota Mining and Manufacturing (3M) conducted an in-house motor system performance optimisation project. Using a systematic facility-by-facility approach, the company formed a team that evaluated approximately 1,000 electric motor systems in 29 buildings at the 3M Center to identify feasible projects.

One of the overarching objectives of this project was to emphasize the methodology that was developed to carry out a project of this magnitude, rather than a specific technology or application. To identify projects that could increase productivity and reduce energy consumption, cost, and emissions, 3M developed the following 9-step approach:

1. Locating and identifying equipment;
2. Documenting the type of motor system, operational requirements and use (including field measurements), type of system and motor controls, and nameplate information.
3. Analysing the efficiency of an existing system, operational use vs. operational need, and present energy consumption;
4. Developing technical options, evaluating alternatives, calculating savings, estimating cost to implement, and determining financial and operational feasibility;
5. Developing proposals and reports, including system description, opportunities for improvement, and recommendations;
6. Presenting feasible proposals to management for funding approval, following up, and obtaining authority for expenditure;
7. Implementing the project(s);
8. Following up with measurements and monitoring, comparing actual savings to calculated savings, and reporting the results; and
9. Communicating activities and progress to steering committee and Building Energy Teams.

Using this systematic approach, the 3M Motor Challenge team identified several energy-saving opportunities in Building 123 (one of the first buildings that their specialist project team assessed). These improvements include the following:

1. Upgrading the Research Pilot Plant Air Supply
2. Upgrading the Reheat Water Supply System
3. Upgrading the Supply Air Fans
4. Energy-Efficient Motors Retrofit

The net cost of the improvement works completed in Building 123 was $79,499 with an annual cost savings of $77,554, which yields a simple payback of 1.03 years. In addition to saving energy, the upgrades also provide up-to-date information on the building's motor systems, identification of required maintenance, and additional savings from matching flow or pressure supply to system requirements.

When applied to all buildings at the 3M Center, the systematic approach to performance optimisation is estimated to save approximately 10,821 MWh and reduce demand by 468 kW annually. With estimated annual savings of $823,000 and a net project cost of $1,600,000, the projects will have a net payback of only 1.9 years.

Author/Publisher: United States Department of Energy
Source: Optimizing Electric Motor Systems at a Corporate Campus Facility (energy.gov)

4 Pumping Systems

4.1 Overview

A pumping system consists of one or more pump(s) including the motor, drive, controls, and distribution pipework including fittings and accumulators.

Seqwater pumping systems are generally used within treatment facilities and for the movement of water from reservoirs, or within the network grid to distribution retailers. Pumps within the treatment plant setup may include systems such as backwash, sludge, filtrate, service water and dosing.

Pumping systems will typically include duty/standby pumps and pipework for the raw and treated networks.

4.2 Efficiency Considerations

The following table outlines the processes and considerations that should be followed to determine energy efficient outcomes at each project phase.

These must be implemented by the relevant discipline in the project Design Team, the Sustainability Engineer/Consultant, and the Quantity Surveyor.

Table 4-1 Energy efficiency considerations for pumping systems

Project Phase	Consideration	Deliverable
Project Planning	• Identify the project specific pumping requirements and applications	☐ Detailed Business Case
Preliminary Design	• Define the type of pumps to be utilised with consideration for energy efficiency • WOL assessment	☐ Preliminary Design Report ☐ WOL Report
Detail Design	• Pipework sizing • Pipework pressure loss • Low-loss valves and fittings • Pump selection • Pump installation • Variable speed drives (VSDs)[4] • Monitoring and BMS	☐ Detail Design Report – Including section on energy efficiency
Tender	• Assess Tender responses for energy efficiency implementation	☐ Tender Evaluations
Construction	• Installation as per design and manufacturer requirements • Review of commissioning results for correct operation	☐ Inspection Reports ☐ Commissioning Reports
Post Practical Completion	• Monitoring of system operation • Trending, data logging and fine tuning of pump operation • General maintenance	☐ Ongoing Maintenance Reports

[4] Refer to Section 9 for information concerning variable speed drives.

4.3 Technical Details

The information presented in Table 4-2 expands on the energy efficiency considerations that are referenced in Table 4-1.

Table 4-2 Description of efficiency considerations for pumping systems

Efficiency Consideration	Description
WOL assessment	• Perform a whole a life (WOL) assessment during the preliminary design stage detailing energy efficiency considerations and feasibility for the project specific requirements. The pump WOL assessment must include the following parameters as a minimum in the analysis: o Capital cost o Ongoing cost o Annual power consumption o Net payback period o Motor size o DOL/VSD o Load factor o Power factor o Duty % o Price of electricity o Price for demand o Tariff structure (peak/off-peak etc.) o Asset life o Operation & maintenance o Pump performance curve o Best efficiency point o System curves o Pump power curve o Required flow rates
Pipework sizing	• Size pipework with consideration for pressure loss (Pa/m) and pipe velocity (m/s). • Size pipework for suitable velocities to reduce pipework frictional pressure losses in straight pipework, fittings and bends. • Water velocity should be considered with respect to the self-cleaning velocity.
Pipework pressure loss	• Minimise pipework pressure loss caused by flow obstructions, sharp bends, expansions and contractions. • Optimise pipework reticulation by minimising unnecessary long runs of pipework and excessive transitions. • Consider locality of pump installations to minimise pipe lengths and optimise distribution pipework. • Pipework bends should be long radius type. • Provide smooth pipework transitions for low pressure loss and to reduce energy losses in the pumping system. • Pipework should be cleaned at regular intervals in accordance with maintenance schedules to avoid increased pressure loss.
Low-loss valves and fittings	• Provide a cost benefit analysis specific to the project for implementation of low-loss valves and fittings in the pumping system. • Low-loss valves and fittings reduce the overall pressure loss in the system and help alleviate any restrictions to water flow.

Efficiency Consideration	Description

Pump selections	• Pumps should be selected to prioritise pump performance and 'best fit' to suit the project specific requirements and design duty. This is to ensure the pumping system is the most robust and resilient system possible.
	• Pump selections should consider energy efficiency with details included in the WOL cost benefit analysis, however the priority for Seqwater systems is for optimal pumping system performance before energy efficiency.
	• Pump selections should consider utilising VSD's for variable speed applications and utilising modern digital control systems.
	• Pumps should be capable of maintaining operation with small future capacity increases as needed by the project specific requirements. Large future capacity increases should be via new pumps or replacement pumps. This is to prevent oversizing the pumps in the initial stage leading to increased energy usage.
	• Ensure final pump technical data submissions including the following details:
	  o System pressure drop calculations.
	  o Pump performance curves showing head, flow, power and duty points.

Pump installation	• The ambient temperature in the pump enclosure or plantroom should not exceed the manufacturer's specification to prevent loss of pump efficiency or performance of the system.
Variable speed drives	• Provide a cost benefit analysis for incorporating variable speed drives into the pumping system detailing initial capital cost, running costs, annual energy consumption and payback period, refer to WOL assessment requirements. • Adding a VSD to a fixed speed pump will generally decrease the overall system efficiency due to the inherent losses associated with a VSD. • Variable speed operation allows for the pumping speed to closely match the desired operating setpoint, system demand or best efficiency point, as opposed to operating at full speed continuously, therefore saving energy. • VSD selection should also consider control strategies whereby pump speed can be modulated to operate at a lower more efficient operating point, which moves water over a certain period of time to improve efficiency as opposed to operation at a higher flow rate profile. • Variable speed pumping control algorithms should utilise flow and pressure control.
Monitoring and BMS	• Consider thorough commissioning to achieve design performance and post-construction fine tuning of the pumping system to reduce energy consumption. • Consider monitoring pump operation with a building management system to allow for trend logging and fine tuning of plant operation post commissioning. • The project design stages should incorporate detailed descriptions of the proposed pump monitoring requirements, including pump efficiency measurements. Pump efficiency can be conventionally measured using the flow and pressure technique or via new technologies such as thermal efficiency measurement. • Configure energy performance indications for system energy metering. • Consider implementation of an energy management system to optimise plant operation and staging of pumps based on ongoing monitoring. • Consider water metering and reporting to a BMS which will allow water usage monitoring and detection of leaks. Detection of water leaking from the system is important as this is wasted energy. • A BMS should record information such as pump run hours, differential pressures, flowrate, electrical energy usage, VSD data and field sensors. The BMS should provide continuous data logging of equipment including trending graphics.

4.4 Additional Materials

Table 4-3 includes references to additional technical documentation concerning pumping systems.

Table 4-3 Supplementary materials supporting energy efficient pumping systems

Related Energy Efficiency Consideration	Document Publisher (Link)	Relevance
Various	Electrical Engineering Portal https://electrical-engineering-portal.com/14-energy-efficiency-improvement-opportunities-in-pumping-systems#:~:text=The%20use%20of%20multiple%20pumps%20is%20often%20the,systems.%20Parallel%20pumps%20offer%20redundancy%20and%20increased%20reliability.	Electrical Engineering Portal have developed a technical article outlining 14 energy efficiency improvement opportunities for pumping systems.
Various	United States Office of Energy Efficiency & Renewable Energy (EERE) https://www.energy.gov/eere/amo/pump-systems	The office of EERE have developed a comprehensive collection of fact sheets, case studies, and other technical publications regarding energy efficient pump systems.
Efficient Design	Water Well Journal (WWJ) https://waterwelljournal.com/designing-efficient-and-effective-pumping-systems/	WWJ have published an article on the design considerations available to project managers to ensure that an energy efficient pumping system is developed.
Procurement	Global Water Research Coalition https://edepot.wur.nl/175846	The Global Water Research Coalition has issued a comprehensive report concerning energy efficiency in the water industry. The report includes a section designated to pumps and ensuring that these systems are fit for purpose.

4.5 Case Studies

4.5.1 Bore pump upgrades for a Burnett fodder farm

Following a whole of system review of a Burnett fodder farm, an auditor recommended upgrading 130 metres of 100mm PVC pipeline to 150mm PVC, which was estimated to reduce the system's annual energy consumption by over 17,000 kWh at a saving of $4,500 per annum.

One of the bore pumps comprising this system was also due to be replaced with a new pump and motor of approximately the same size. This new, high efficiency model will deliver an additional five litres of pumped water per second, which will reduce the site's pumping hours by 20% and total energy consumption by an estimated 30%.

Author/Publisher: Queensland Farmer' Federation

Source: Energy efficient pumping savings - Pump Industry Magazine

4.5.2 Melbourne Water's Effluent Reuse Water Pump Station No. 6 (ERW6)

There are six pumps at Melbourne Water's Effluent Reuse Water Pump Station No.6 (ERW6). Melbourne Water sought to optimise the control system for these pumps to eliminate energy wastage without compromising service levels. The pumps were previously operated with a pressure set point of 51 metres head. To achieve their objectives for this system, the control algorithm was changed from pressure control to flow and pressure control so that the operating pressure is derived according to the ERW6 delivery flow rate.

Pre-intervention, on an annual basis, these pumps were operational for approximately 11,325 hours, consumed 2,573 MWh, and pumped 13.1 GL of effluent (195 MWh/GL). In the 12 months' following this change, these pumps were operational for 13,908 hours, consumed 2,631 MWh, and pumped 14.2 GL of effluent (185 MWh/GL).

Author/Publisher: Global Water Research Coalition

Source: Microsoft Word - 10CL113-4.doc (wur.nl)

5 Compressed Air Systems

5.1 Overview

A compressed air system consists of air compressors including motors, dryers, receivers, air filters, pressure regulators and a pipework distribution network. A compressed air system will also include ancillary equipment in the pipework distribution system such as isolation valves, pressure gauges, safety pressure relief valves, non-return valves and pressure switches for alarms.

Typical applications for compressed air include actuator control, cleaning of devices, drying of equipment, powering machinery, scrubbing filters and water treatment process. At Seqwater compressed air has different low and high-pressure requirements.

Low pressure air, generally provided by blowers is used in the filtration process as an air scour (agitation) to initiate the filter backwash sequence, these blowers are generally low use assets.

High pressure air is generally of four types:

- Installations which supply a constant and non-varying supply of compressed air to form a mixing bubble curtain in dams. These systems generally run continuously.
- Compressed air systems supplying a continuous feed of compressed air in the production of ozone and only operate when the WTP's are in operation.
- Compressed air systems that supply operating energy for use in the operation of the plant (i.e., valve actuation).
- Supply of compressed air for the use in DAF applications.

5.2 Efficiency Considerations

The following table outlines the processes and considerations that should be followed to determine energy efficient outcomes at each project phase.

These must be implemented by the relevant discipline in the project Design Team, the Sustainability Engineer/Consultant, and the Quantity Surveyor.

Table 5-1 Energy efficiency considerations for compressed air systems

Project Phase	Consideration	Deliverable
Project Planning	• Identify the need for compressed air systems and project specific applications	☐ Detailed Business Case
Preliminary Design	• Define the type of compressors to be utilised with consideration for energy efficiency • WOL assessment	☐ Preliminary Design Report ☐ WOL Report
Detail Design	• Pipework sizing • Pipework pressure loss • Low-loss valves and fittings • Compressor selections • Compressor installation • Compressor control • Air receivers • Air filter selection • Air metering	☐ Detail Design Report – Including section on energy efficiency
Tender	• Assess Tender responses for energy efficiency implementation	☐ Tender Evaluations
Construction	• Installation as per design and manufacturer requirements • Review of commissioning results for correct operation	☐ Inspection Reports ☐ Commissioning Reports
Post Practical Completion	• Monitoring of system operation • Trending, data logging and fine tuning of compressor operation • General maintenance • Monitoring equipment to ensure prompt leak detection	☐ Ongoing Maintenance Reports

5.3 Technical Details

The information presented in Table 5-2 expands on the energy efficiency considerations that are referenced in Table 5-1.

Table 5-2 Description of efficiency considerations for compressed air systems

Efficiency Consideration	Description
WOL assessment	• Perform a whole a life (WOL) assessment during the preliminary design stage detailing energy efficiency considerations and feasibility for the project specific requirements. The compressed air WOL assessment must include the following parameters as a minimum in the analysis: o Capital cost o Ongoing costs o Annual power consumption o Net payback period o Motor size o DOL/VSD o Load factor o Power factor o Duty % o Price of electricity o Price for demand o Tariff structure (peak/off-peak etc.) o Asset life o Operation & maintenance o Required volume flow rate o Required pressure
Pipework sizing	• Ensure pipework is sized at a proper diameter to minimise friction losses. • Size pipework with consideration for pressure loss (Pa/m) and velocity (m/s). • Size for suitable pressure loss to reduce pipework friction losses. • Size for suitable velocity to reduce fitting and sharp bend losses.
	• Minimise pressure loss caused by flow obstructions, bends, expansions and contractions. • Optimise pipework reticulation by minimising unnecessary long runs of pipework and excessive transitions. • Consider locality of compressor installations to minimise pipework lengths. • Consider leak detection in the pipework system to prevent wasted energy.
Low-loss valves and fittings	• Consider providing design specifications for low-loss valves and fittings in the compressed air pipework distribution system. • Low-loss valves and fittings reduce the overall pressure loss in the system and help alleviate any restrictions to compressed air flow.

Efficiency Consideration	Description
Compressor selections	• Compressors should be selected with consideration for energy efficiency. Consider energy efficient compressor selections and latest technologies utilising variable speed operation, digital controls and multiple compressors modules for staged operation. • The design must include a whole of life cost benefit analysis for different compressor types comparing costs, efficiencies, payback, and suitability for the specific project application i.e. flow rate, pressure, running time, sustainability targets etc. • Typical positive displacement compressor technologies include Rotary Screw, Rotary Scroll, Rotary Vane and Reciprocating Compressors. Rotary type compressors are generally more efficient than reciprocating compressors and should be utilised for compressed air systems. • The efficiency of air compressors, expressed as the volume of air delivered to the pipeline system at a certain pressure (after losses in the drying system and filtration system) per kilowatt-hour (kWh), should be stated by the supplier of the system.
Compressor installation	• The installation of two or more compressors for larger systems is recommended because of the possible large difference between maximum and minimum flow requirements causing inefficient running of a large compressor with an excessive number of starts during normal demand. • The ambient temperature in the compressor enclosure or plantroom should not exceed the manufacturer’s specifications to prevent loss of efficiency or performance of the system.
Compressor control	• Controls should be arranged so that compressors are able to supply the system in turn or simultaneously on demand. • It is possible for compressors to generate air pressure higher than what is required by the downstream equipment or systems, to save energy the system air pressure should be set at a level marginally higher than the system requires, whilst allowing for pipework pressure losses in the system. • For multiple compressor sets, efficient compressor operation and compressor staging should be prioritised, whereby the most efficient compressor/s operate to meet the system demand.
Air receivers	• Consider providing an air receiver in the compressed air system to minimise the number of compressor starts per hour based on system design flow. • Adding an air receiver to an existing system will reduce the number of compressor starts each hour, therefore saving on compressor energy. An air receiver may also assist with rectifying or preventing compressor faults if the compressors are starting too often.
Air filter selection	• Ensure compressed air filters are selected to account for peak design flow rates and low-pressure loss. • It’s recommended that differential pressure sensors and alarms are provided for filters so that filters can be replaced promptly when dirty. Clean filters greatly reduce system pressure drop. • If the building/facility contains a Building Management System it is recommended to interface alarms with the BMS. Provide a cost benefit analysis for integration of the compressed air system with the BMS.
Air metering	• Consider metering compressed air usage to different areas and/or equipment to identify opportunities for energy savings and optimise plant operation profiles. • Air metering allows high air usage equipment to be identified and plant operation optimised as this equipment would be driving the higher energy usage. • Air metering allows leaks in the system or faulty equipment to be identified promptly and rectified therefore reducing wasted energy.

5.4 Additional Materials

Table 5-3 includes references to additional technical documentation concerning compressed air systems.

Table 5-3 Supplementary materials supporting energy efficient compressed air systems

Related Energy Efficiency Consideration	Document Publisher (Link)	Relevance
Various	Victorian State Government Department of Environment, Land, Water and Planning https://www.victorianenergysaver.vic.gov.au/energy-advice-for-business/managing-your-energy-consumption/equipment-and-technologies-case-studies-and-guides/compressed-air	The Victorian Government's Department of Environment, Land, Water and Planning has compiled a comprehensive repository of case studies, fact sheets, guides and other tools regarding the design and operation of energy efficient compressed air systems.
Various	NSW Office of Environment & Heritage https://www.environment.nsw.gov.au/resources/business/compressed-air-guide-170257.pdf	The NSW Office of Environment & Heritage, with contributions from The Carnot Group and Northmore Gordon Pty Ltd, have developed a comprehensive guide concerning opportunities to improve the efficiency of compressed air systems.
Various	Sustainability Victoria https://www.sustainability.vic.gov.au/energy-efficiency-and-reducing-emissions/in-a-business/plant-and-equipment-energy-efficiency/reduce-compressed-air-costs-in-your-business	Sustainability Victoria have produced a fact sheet regarding ways to improve the efficiency of compressed air systems during operation. These initiatives include adhering to regular maintenance schedules, installing timers and operational controls, and considering the feasibility of a variable speed drives.

5.5 Case Studies

5.5.1 Australian Company Focuses on Compressed Air Waste & Quality

The engineering manager of a southern NSW cereal manufacturer sought external expertise to reduce the extent of compressed air leakage in the plant. Using advanced diagnostic equipment, the first survey identified 264 leaks, which were easily fixed by local contractors. Within one year of the initial surveys, compressed air leakage had been reduced enough to allow the site to operate using two air compressors rather than three. This provided significant energy savings that are estimated to be approximately $168,000 per annum.

Publisher: Basil V.R. Greatrex (BVRG)

Source: Australian Company Focuses on Compressed Air Waste & Quality | Compressed Air Best Practices

5.5.2 Downer EDI Rail demonstrates savings through upgrading air compressors

An Ultrasonic Compressed Air Survey was undertaken at the Downer Auburn Maintenance Centre (AMC) to locate, tag, report and quantify the compressed air leaks across the system.

Using the latest in Ultrasonic technology, Energy & Carbon Solutions was able to identify the following outcomes. The current system utilises two (2) Champion CSF 18 Compressors (18kW, 108 CFM) in a duty and standby configuration. The compressors were recently overhauled with new air-ends, which should extend the life of the machines by 5 years plus. It was found that over 70.7% of one of the air compressors output was being lost in 25 separate air leaks, which, once resolved, will equate to an operational saving of $16,413 per annum and a reduction of over 139 tCO_2-e.

Publisher: Energy & Carbon Solutions

Source: https://www.energyandcarbon.com.au/project/downeredirail_auburn/

6 Heating, Ventilation, and Air Conditioning (HVAC) Systems

6.1 Overview

HVAC systems consist of both the water/refrigerant and air distribution sides of the system. These systems may include equipment such as chilled water (CHW) plant including chillers, cooling towers, air handling units, chilled water and condenser water pumps, water treatment systems, buffer tanks, heat exchangers and distribution pipework.

Refrigeration systems including direct expansion (DX) or variable refrigerant flow (VRF) systems including refrigerant pipework, air-conditioning plant including compressors, fans, filters and coils.

HVAC systems may also include equipment such as ventilation fans, electric heaters, heat recovery units, pre-conditioning units, ductwork for air distribution and grilles.

Seqwater HVAC systems commonly serve office spaces, workshops, water quality labs, electrical equipment rooms and battery rooms to provide comfort heating and cooling for habitable spaces or process cooling for non-habitable spaces. Air-conditioning and dehumidification is used by Seqwater to control operating environments for plant operation as well as human occupation.

6.2 Efficiency Considerations

The following table outlines the processes and considerations that should be followed to determine energy efficient outcomes at each project phase.

These must be implemented by the relevant discipline in the project Design Team, the Sustainability Engineer/Consultant, and the Quantity Surveyor.

Table 6-1 Energy efficiency considerations for HVAC systems

Project Phase	Consideration	Deliverable
Project Planning	• Identify the need for HVAC systems and investigate different options for the project Identify whether the project will incorporate Green Star or NABERS building ratings	☐ Detailed Business Case ☐ Green Start / NABERS Report
Preliminary Design	HVAC options considered: • System type (Chilled water or DX) • Air-cooled or water-cooled plant • Refrigerant type • Packaged, Split, VRF, DX systems • Centralised or distributed plant • Air distribution methods • Heat recovery systems • Thermal zoning strategies • Façade optimisation and passive design to reduce cooling / heating loads. WOL assessment	☐ Preliminary Design Report – Including HVAC options analysis ☐ Façade Optimisation Report ☐ WOL Report

Project Phase	Consideration	Deliverable
Detail Design	Controls methodology review for energy efficiency opportunities including: • Widened dead band • Relaxed comfort conditions • Scheduling • After hours controls • CO_2 demand control • Reduce outdoor air Design Considerations: • Heat recovery • Economy cycle • Ductwork/pipework insulation • Pressure drops Equipment selection	☐ Detail Design Report – Including section on energy efficiency ☐ Draft Functional Descriptions for HVAC system controls and BMS
Tender	Assess Tender responses for energy efficiency implementation	☐ Tender Evaluations
Construction	• Installation as per design and manufacturer requirements • Review of commissioning results for correct operation Consider the services of an Independent Commissioning Agent for improved commissioning outcomes	☐ Inspection Reports ☐ Commissioning Reports
Post Practical Completion	• Monitoring of system operation • Trending, data logging and fine tuning of HVAC system operation • Ongoing building tuning General maintenance	☐ Ongoing Maintenance Reports ☐ Building Tuning Report (after one year of operation)

6.3 Technical Details

Efficiency Consideration	Description
WOL assessment	• Perform a whole a life (WOL) assessment during the preliminary design stage detailing energy efficiency considerations and feasibility for the project specific requirements. The heating, ventilation and air conditioning WOL assessment must include the following parameters as a minimum in the analysis: ○ Capital cost ○ Ongoing costs ○ Annual power consumption ○ Net payback period ○ Motor size ○ DOL/VSD ○ Load factor ○ Power factor ○ Duty % ○ Price of electricity ○ Price for demand ○ Tariff structure (peak/off-peak etc.) ○ Asset life ○ Operation & maintenance ○ Coefficient of performance (COP) ○ Chiller IPLV / NPLV ○ Fan / pump / motor efficiencies
Widened dead band	• A control method where a wider range of temperatures are acceptable. By widening the dead band, there is a greater duration where neither heating or cooling occurs. • Air-conditioning must have a control dead band of not less than 2°C, except where a smaller range is required for specialised applications[1]
Relaxed comfort conditions	• Similar to widening the dead band, relaxing comfort conditions allows temperatures to become warmer and cooler before heating or cooling is triggered, meaning plant is not operating as frequently or being driven as hard.
Scheduling	• Scheduling ensures that the HVAC and refrigeration systems only operate when required. • An air-conditioning or mechanical ventilation system must be capable of being deactivated when the building or part of a building served by that system is not occupied[1] • When deactivated, must close any motorised outdoor air or return air damper that is not otherwise being actively controlled[1] • A time switch must be provided to control[1]: ○ an air-conditioning system more than 2 kWr ○ a heater more than 1 kW ○ a mechanical ventilation system with an air flow rate of more than 1000 L/s • The time switch must be capable of switching electric power on and off at variable pre-programmed times and on variable pre-programmed days. • This does not apply to an air-conditioning system that serves only one sole-occupancy unit in a Class 2, 3 or 9c building; or a Class 4 part of a building; or a conditioned space where air-conditioning is needed for 24-hour continuous use. For detailed requirements refer to the NCC 2019.
	• After hours controls are usually a push button that switch on air conditioning on a per zone basis only when required, usually for a period of 2 hours.

<table>
<tr><th>Efficiency Consideration</th><th>Description</th></tr>
<tr><td>CO2 demand control</td><td>Carbon dioxide demand control ventilation reduces the amount of incoming fresh outdoor air to the air-conditioning system by measuring the CO2 ppm (parts per million) within the occupied space or return air ductwork. The control system then modulates the outdoor air dampers based on the measured CO2 level and therefore reduces energy consumption.
CO2 demand control ventilation must comply with the requirements detailed in AS1668.2.</td></tr>
<tr><td>Reduce outdoor air</td><td>Reducing the outdoor air being processed by an air-conditioning system can reduce the overall HVAC system energy consumption. This can be achieved by providing suitable air filtration systems and high efficiency rated air filters within the air-conditioning plant.
Outdoor air ventilation rates and filtration must comply with the requirements detailed in AS1668.2.</td></tr>
<tr><td>Heat recovery</td><td>Heat recovery systems recover energy from the return air to preheat or precool incoming fresh outdoor air. Heat recovery systems may include rotary heat exchanger wheels or plate heat exchangers.
Heat recovery systems may be either sensible only or sensible and latent type depending on the air-conditioning system operation and local climate.
Heat recovery systems should typically be utilised for areas with high occupancy and high outside air requirements such as meeting rooms, conference rooms and laboratories.</td></tr>
<tr><td>Economy cycle</td><td>Economy cycle allows heating and cooling to switch off and air conditioning plan to run with fans only, supplying fresh outdoor air to the space when ambient conditions allow this to occur within the designated comfort conditions.
Relaxing comfort conditions allow economy cycle to run more of the year.
Requirements for an outdoor economy cycle, excluding climate zone 1 or where dehumification control is needed[1]:
<table>
<tr><th>BCA Climate Zone</th><th>Total air flow rate requiring an economy cycle (L/s)</th></tr>
<tr><td>2</td><td>9000</td></tr>
<tr><td>3</td><td>7500</td></tr>
<tr><td>4</td><td>3500</td></tr>
<tr><td>5</td><td>3000</td></tr>
<tr><td>6</td><td>2000</td></tr>
<tr><td>7</td><td>2500</td></tr>
<tr><td>8</td><td>4000</td></tr>
</table></td></tr>
</table>

Efficiency Consideration	Description
Ductwork and pipework insulation	• Insulation of ductwork and pipework reduces wasteful heat gain or loss, hence reducing overall energy consumption. Ductwork and pipework insulation must comply with the minimum performance requirements set out in the current versions of the NCC and AS1668.2. • Flexible ductwork minimum R-value of 1.0[1] • Ductwork minimum R-value[1]:

Ductwork location	Climate zone 1 to 7	Climate zone 8
Conditioned space	1.2	2.0
Exposed to sunlight	3.0	3.0
All other locations	2.0	3.0

• Pipework minimum R-value by pipe diameter[1]:

Fluid temp	< 40mm	40 – 80mm	80 – 150mm	> 150mm
< 2 °C	1.3	1.7	2.0	2.7
2 – 20 °C	1.0	1.5	2.0	2.0
30 – 85 °C	1.7	1.7	1.7	1.7
> 85 °C	2.7	2.7	2.7	2.7

• Vessel, heat exchanger, tank minimum R-value[1]:

Fluid temp	R-value
< 2 °C	2.7
2 – 20 °C	1.8
30 – 85 °C	3.0
> 85 °C	3.0

Efficiency Consideration	Description
Pressure drop	• Pressure drop increases the load of mechanical equipment such as fans and air-conditioning units therefore reducing energy efficiency. Reducing pressure drop can make a system more efficient as the air or water can run with less restrictions in the system therefore requiring less fan and pump power. • Ductwork must not exceed 1 Pa/m along all sections of rigid and flexible ductwork in the index run[1] • Flexible ductwork must not be longer than 6m in any duct run[1] • Turning vanes must be included in all rigid ductwork elbows of 90 degrees or more, unless a long radius bend is used[1] • Maximum coil pressure drop[1]:

Number of rows	Maximum pressure drop (Pa)
1	30
2	50
4	90
6	130
8	175
10	220

• Air filters must not exceed the design filter pressure drop when clean at an air velocity of 2.5m/s. Maximum clean filter pressure drop[1]:

Minimum efficiency value	Maximum pressure drop (Pa)
9	55
11	65
13	95
14	110

• Maximum louvre pressure drop[1]:

<table>
<tr><th>Efficiency Consideration</th><th>Description</th></tr>
<tr><td></td><td>
<table>
<tr><th>Louvre Type</th><th>Maximum pressure drop (Pa)</th></tr>
<tr><td>Single Stage</td><td>30</td></tr>
<tr><td>Two Stage</td><td>60</td></tr>
<tr><td>Acoustic</td><td>50</td></tr>
<tr><td>Non-weatherproof</td><td>30</td></tr>
</table>
Maximum mechanical equipment pressure drop[1]:
<table>
<tr><th>Mechanical Equipment</th><th>Maximum pressure drop (Pa)</th></tr>
<tr><td>VAV box</td><td>25</td></tr>
<tr><td>VAV box with elec reheat</td><td>100</td></tr>
<tr><td>Roof cowl</td><td>30</td></tr>
<tr><td>Attenuator</td><td>40</td></tr>
<tr><td>Fire damper</td><td>15</td></tr>
<tr><td>Balancing damper (index run)</td><td>25</td></tr>
<tr><td>Supply air diffuser</td><td>40</td></tr>
<tr><td>Exhaust grille</td><td>30</td></tr>
<tr><td>Transfer duct</td><td>12</td></tr>
<tr><td>Door grille</td><td>12</td></tr>
<tr><td>Active chilled beam</td><td>150</td></tr>
</table>

The pressure drop tables above do not apply to:
Fans in un-ducted air-conditioning systems with a supply air capacity of less than 1000 L/s
Smoke spill fans, except where also used for air-conditioning or ventilation
The power for process-related components
Kitchen exhaust systems
Maximum pipework pressure drop for various types of air-conditioning pumping systems are detailed in NCC section J5.7.

</td></tr>
<tr><td>Equipment selection</td><td>

Equipment should be selected for efficiency. WOL costs can justify increased capital expenditure if equipment has a lower lifecycle price. Selection of equipment with variable speed drives and motors can reduce overall energy consumption.
Air-conditioning plant with an airflow of more than 1000 L/s, must have a variable speed fan when its supply air quantity is capable of being varied[1]
Mechanical ventilation systems with an airflow of more than 1000 L/s, must have a variable speed fan unless the downstream airflow is required by NCC Part F4 to be constant[1]
Mechanical equipment for air-conditioning systems such as pumps, chillers, air-conditioning units and heat rejection equipment must comply with the minimum efficiency requirements detail in NCC section J5.

</td></tr>
<tr><td>Commissioning</td><td>

Commissioning is the testing of systems after installation. It is essential to ensuring that a system is operating as per the design intent and the commissioning process is the best opportunity to fix controls issues that could be costly in terms of energy usage in operation.

</td></tr>
<tr><td>Building Tuning</td><td>

Building tuning involves monitoring and improving the performance of building services systems during operation. The goal is to 'tune' the building services controls for an improved level of energy efficiency throughout the seasons, while maintaining or improving occupant comfort.
Building energy performance can be monitored by data logging and trending the various mechanical equipment, sensors, control devices and ambient weather conditions. Building management system tuning should be based on factual historical data to reduce energy consumption and optimise the system operation.
Refer to recognised industry publications such as AIRAH, ASHRAE and CIBSE for detailed mechanical performance guidelines.

</td></tr>
</table>

[1] NCC 2019 - National Construction Code 2019 Section J5 Air-conditioning and ventilation systems

6.4 Additional Materials

Table 6-3 includes references to additional technical documentation concerning HVAC systems.

Related Energy Efficiency Consideration	Document Publisher (Link)	Relevance
System type design and selection for efficiency	*The Australian Institute of Refrigeration, Air conditioning and Heating (AIRAH)* DA01 Centrifugal Pumps https://www.airah.org.au/DA_manuals/Manuals/DA_Manuals/	AIRAH is the leading industry Australian body for advocacy and expertise in the area of HVAC and refrigeration for the built environment. AIRAH's Design Application (DA) manuals are technical publications to assist you in your day-to-day work in the HVAC&R industry. AIRAH continues to update its DA manuals to align them to industry standards and maintain best practices. DA01 is a guideline for the selection and application of centrifugal pumps used in the building services industry for pumping water and other fluids.
	AIRAH DA20 Humid Tropical Air Conditioning https://www.airah.org.au/DA_manuals/Manuals/DA_Manuals/	DA20 explores the topic of comfort in hot tropical climates, starting from the very fundamentals of climate, thermal comfort, human response, and adaptive comfort. The manual covers natural, mechanical and hybrid comfort cooling systems, as well as building design and moisture-management strategies.
	National Construction Code (NCC) Part J5 https://ncc.abcb.gov.au/	NCC provides the legal requirement for HVAC system operation and air-conditioning system control
Façade optimisation	Chartered Institution of Building Services Engineers (CIBSE) Society of Façade Engineering https://www.cibse.org/society-of-facade-engineering-sfe	For buildings to achieve a high energy efficiency and create a comfortable environment for occupants, there must be appropriate dialogue between architects, façade engineers, building services engineers, structural engineers, and contractors. The Society of Façade Engineering brings these people together in a forum where they can work together to advance knowledge and practice in facade engineering.
	Green Building Council of Australia (GBCA) Building Technical Manual https://new.gbca.org.au/green-star/rating-system/buildings/	The GBCA Green Star Technical Manual provides a modelling methodology for best practice façade design in the energy section.

Related Energy Efficiency Consideration	Document Publisher (Link)	Relevance
HVAC controls optimisation	AIRAH DA04 Air System Balancing – in HVAC https://www.airah.org.au/DA_manuals/Manuals/DA_Manuals/	DA04 is a manual on the testing, adjusting and balancing of air distribution systems in heating, ventilation, air conditioning and refrigeration (HVAC&R) applications. The accurate measurement and adjustment of airflow rates using a recognised and reliable process during commissioning ensures that plant and equipment are adjusted and set correctly to meet the specified design operating conditions. For air conditioning systems, activities ensure that operational variables are adjusted and set correctly to create the design comfort conditions, including volume, temperature, humidity, pressure, air movement and air quality set points or targets within the occupied space.
	AIRAH DA24 Hydronic System Balancing – in HVAC https://www.airah.org.au/DA_manuals/Manuals/DA_Manuals/	DA24 is a publication on the commissioning and testing, adjusting and balancing (TAB) of hydronic water systems in heating, ventilation, air conditioning and refrigeration (HVAC&R) applications. During commissioning, the accurate measurement and adjustment of water flow rates using a recognised and reliable process ensures that plant and equipment are adjusted and set correctly to meet the specified design operating conditions.
Heat recovery	Australian Government Department of Agriculture, Water and Environment Heat Pump and Heat Recovery Technologies Paper https://www.environment.gov.au/system/files/energy/files/hvac-factsheet-heat-pump-tech.pdf	Paper provides overview of technology and potential benefits.
Economy cycle	National Construction Code (NCC) Part J5 https://ncc.abcb.gov.au/	NCC provides the legal requirement for economy cycle operation.
	AIRAH DA19 HVAC&R Maintenance https://www.airah.org.au/DA_manuals/Manuals/DA_Manuals/	DA19 has been the definitive reference for HVAC&R maintenance in Australia for more than 20 years. It is used throughout the Australian property, facility management and HVAC&R maintenance industries. Now in its fourth edition, DA19 has been developed with considerable industry engagement and features significant updates relating to energy efficiency, system sustainability, asset management and the digitisation of maintenance (smart maintenance).
	AIRAH DA28 Building Management and Control Systems (BMCS) https://www.airah.org.au/DA_manuals/Manuals/DA_Manuals/	DA28 manual is intended to help building practitioners understand and manage BMCS and building controls. It outlines a generic process for the design and implementation of control systems for buildings.

Related Energy Efficiency Consideration	Document Publisher (Link)	Relevance
Insulation	NCC Part J5 https://ncc.abcb.gov.au/	NCC provides the legal requirement for ductwork and pipework insulation.
	AIRAH DA03 Ductwork for Air Conditioning https://www.airah.org.au/DA_manuals/Manuals/DA_Manuals/	DA03 features detailed guidelines for designing air conditioning ductwork systems including the benefits of ductwork insulation.
Pressure drop	AIRAH DA03 Ductwork for Air Conditioning https://www.airah.org.au/DA_manuals/Manuals/DA_Manuals/	DA03 features detailed guidelines for designing air conditioning ductwork systems including design to reduce pressure drop for energy efficiency.
	NCC Part J5 https://ncc.abcb.gov.au/	NCC provides the legal requirement for ductwork and pipework pressure drop.
Commissioning and benchmarking	AIRAH DA27 Building Commissioning https://www.airah.org.au/DA_manuals/Manuals/DA_Manuals/	DA27 helps to define and standardise the building commissioning process, its critical steps and the common language.
	CIBSE Commissioning Codes https://www.cibse.org/knowledge/knowledge-items-(1)/publications/commissioning-codes	CIBSE is a global network, registered in the United Kingdom, that supports the Science, Art and Practice of building services engineering, by providing members and the public with first class information and education services
Building tuning, trends, and data logging	AIRAH DA28 Building Management and Control Systems (BMCS) https://www.airah.org.au/DA_manuals/Manuals/DA_Manuals/	DA28 manual is intended to help building practitioners understand and manage BMCS and building controls. It outlines a generic process for the design and implementation of control systems for buildings.

6.5 Case Studies

6.5.1 WT Sustainability no Compromises for a 6 Star Tenancy Fitout

WT Sustainability (WTS) are specialist sustainability consultants for the built environment. WTS took the opportunity, when fitting out their new office in North Sydney, to use in-house expertise and knowledge in integrating sustainable design and construction practice and initiatives.

To achieve their ambitious targets, WTS focused on the high-energy sources of consumption within the tenancy, including supplementary air conditioning, lighting and office equipment. Through careful planning and constant monitoring and review, WTS demonstrated that tenants can achieve a top performing workspace with minimal inconvenience and budget.

Key initiatives were to avoid supplementary air conditioning by integrating enclosed high load spaces into open plan office and balancing the base building air conditioning to suit the tenancy layout.

Technology used included efficient lighting, occupation sensors, timed power circuits, energy meters, laptops, LED LCDs and high efficiency printer/copiers.
An annual financial saving of $6,600 was achieved compared to an ‘average’ office. This equates to an annual energy saving 23,800 kWh and 25 Tonnes of CO_2e.

Publisher: CitySwitch

Source:
https://cityswitch.net.au/Portals/0/Case%20study%20pdfs/CitySwitch%20Case%20Study%20WT%20Sustainability%20final.pdf

6.5.2 Building façade performance and impact on HVAC design and building energy

This study took fictional building is a 10-storey office building. It was modelled as being located in Brisbane and then in Melbourne. The building fabric is a curtain wall construction, with opaque spandrel glass.

Four scenarios were modelled:

- **Scenario 1 – Non-compliant U-value of the windows:** The U-Value of windows was modelled to be 5.7. The SHGC remains unchanged at 0.21. This window is a single-glazed unit with non-thermally broken aluminium frames.
- **Scenario 2 – Non-compliant SHGC of the windows:** The SHGC of windows was modelled to be 0.42. The U-Value remains unchanged. This window is a clear double-glazed unit.
- **Scenario 3 – Window to Wall Ratio (WWR) enlarged:** The WWR was increased from 56% to 75%. The glazing performance is the same as the base case. The equivalent wall-glazing system U-Value in the scenario is 2.28 (non-compliant) and the solar admittance is 0.16 (non-compliant).
- **Scenario 4 – WWR enlarged with compliant solar admittance:** The WWR was increased from 56% to 75%. The SHGC of the glazing was modelled to be 0.17 to achieve the compliant solar admittance (<=0.13). Note that the U-Value of the glazing remain unchanged. As a result, the total system U-Value of wall-glazing construction is not compliant in this scenario. The glazing unit is an argon filled double-glazed unit with low-e and low-iron coating. The wall-glazing system U-Value in the scenario is 2.28 and the solar admittance is 0.13.

The modelling results show that the peak cooling, heating and airflow requirements increase when glazing performance deteriorates or when a large amount of glazing is used in a building.

From a HVAC design perspective, the impacts of deteriorated building fabric design are:

- Increased peak cooling capacity and heating capacity is required. This translates to larger chiller and heating plant systems with modular design and good part load performance.
- Reduced U-value performance associated with swapping a double-glazed unit to a single-glazed unit has substantial impact on heating plant peak capacity (>50% increase), even in a warm climate such as Brisbane.
- Increased airflow capacity is required. This translates to larger ductwork and fan sizes required, including riser spatial requirements.
- Reduced SHGC performance generally has a greater impact on the eastern and western perimeter zones, though it can be seen that in a warmer climate like Brisbane, this has substantial impact on the centre zone and north façade too.

Practitioners are encouraged to prioritise good building fabric design, which has a longer lifecycle (40 to 60 years) relative to HVAC plant (15 to 20 years). Good building fabric design will enable efficient HVAC plant and control to occur – avoiding the use of HVAC plant as a band-aid solution to counter thermal comfort issues related to poor building fabric design.

Author: Grace Foo and Hongsen Zhang

Publisher: AIRAH

Source: https://www.airah.org.au/Content_Files/EcoLibrium/2020/12-20-Eco-technical-paper.pdf

6.5.3 Analysis of energy reduction through HVAC commissioning: A case study of a LEED certified new building

HVAC commissioning is one of the most efficient processes to minimize energy waste and reducing performance gap by verifying and documenting building's entire systems. It is reported that building energy consumption can be reduced up to 20-40% and most building system deficiencies can be addressed through HVAC commissioning.

Despite these benefits, it is often challenging to analyse and quantify building's energy savings of new building project through commissioning due to it is not easy to compare and analyse the actual energy use data and designed/calculated energy consumption.

In this study, a case study of new building's HVAC commissioning was carried out the part of LEED Certification proceeding, and the commissioning results were compared and analysed against designed/calculated energy consumption. The comparison data were used for evaluating dynamic simulation model and energy reduction achievement by HVAC commissioning. Through this paper, it shows that HVAC commissioning is possible to propose the energy reduction with reducing performance gap. Within this paper, the case study building's energy saving was achieved by 5.3% through HVAC commissioning.

Author: Young Ki Kim and Hasim Altan

Publisher: Institute of Electrical and Electronics Engineers (IEEE)

Source: https://ieeexplore.ieee.org/document/8337604/keywords#keywords

7 Power Factor Correction

7.1 Overview

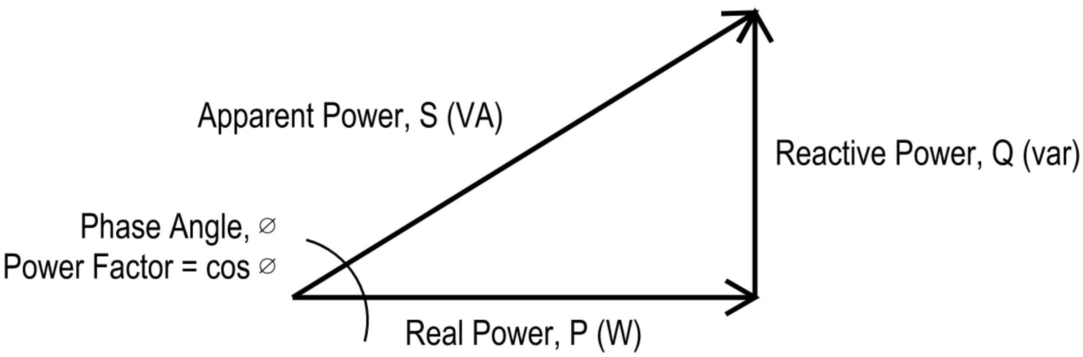
Australian power systems operate at 400V/230V 50 Hz alternating current (AC). In this arrangement, the magnitude of voltage and current changes over time in a sinusoidal fashion, oscillating once every 0.02 seconds (or 50 times every second, 50 Hz).

In power systems that incorporate purely resistive (linear) electrical loads, the voltage and current waveforms remain in phase; that is, they simultaneously experience peak, trough and zero values.

In practice, few electrical loads are truly linear, and most instead incorporate capacitive and inductive elements. This causes the waveforms to shift and become out of phase. The resultant angle between the waveforms is used to derive the power factor being experienced, which is a measure of how matched the wave forms are. The formula for power factor is as follows:

$$\text{pf} = \cos(\emptyset)\text{, where } \emptyset = \text{the angle of the phase difference between the waveforms } (0 - 90°)$$

Figure 7-1 Power system vector diagram



The amount of real (useable) power being delivered by a power system is the product of the voltage, current and the power factor. Voltage and current waveforms that are in phase (operating at a power factor of one, or unity) derive the highest possible real power. When the waveforms are out of phase, the real power delivered is reduced. This occurs when the power factor of the system is of a value less than one.

$$\text{Real power} = V \times I \times \text{pf}$$

In practice, the current waveform typically lags the voltage waveform due to the presence of an overall inductive electrical load caused primarily by large inductive loads such as motors. The nature of these electrical loads is largely unavoidable, and hence the modern-day approach to address this challenge is to install power factor correction systems where required.

To counteract inductive loads, power factor corrections typically incorporate switched capacitor banks to bring the voltage and current waveforms at the site's connection point back into phase, therefore requiring less Apparent Power to operate the same electrical equipment. These systems are typically installed with several 'steps', such that a control system can switch the power factor correction system on and off in stages to respond to real time changes in the electrical load.

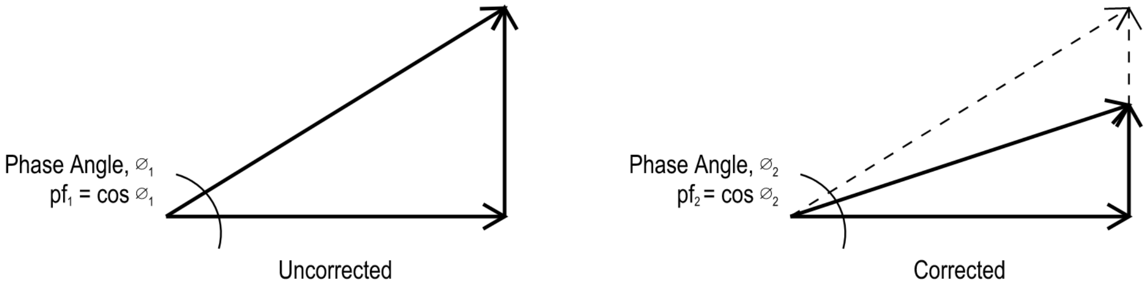


Figure 7-2 Power system vector diagram - uncorrected vs corrected

In the graphic noted above, the magnitude of reactive power in the corrected system is seen to be reduced, compared to that of the uncorrected system. This corresponds to a lesser phase angle ($ø_2 < ø_1$). Correspondingly, the power factor of the corrected system is closer to unity ($pf_2 > pf_1$). This is due to the presence of power factor correction, which offsets a portion of the reactive power. The real power remains constant regardless of the presence of power factor correction.

The apparent power of the corrected system is also seen to be reduced, giving rise to potential savings when demand charges are in place. Demand charges are utility charges that are imposed depending on the magnitude of an installation's maximum apparent power. Imposing demand charges allows utility authorities to encourage consumers to improve the power factor associated with their installation, which provides benefits to the utility authority in the reduced sizing of upstream infrastructure.

More advanced power compensation systems are available which manipulate the distribution systems waveforms to improve power factor correction, these are call Static var compensators. Different manufactures achieve this outcome in different ways, including use of Voltage Source Converters or Static VAR generators. While more expensive to implement, these systems generally have lower ongoing maintenance costs, with components expected to last longer than the capacitors in other systems. They are also "stepless", providing finer control over the amount of correction to the system, allowing tighter adherence to the system's target power factor.

7.2 Efficiency Considerations

The following table outlines the processes and considerations that should be followed to determine energy efficient outcomes at each project phase.

These must be implemented by the relevant discipline in the project Design Team, the Sustainability Engineer/Consultant, and the Quantity Surveyor.

Table 7-1 Energy efficiency considerations for power factor correction

Project Phase	Consideration	Deliverable
Project Planning	• Consider the value of incorporating power factor correction into a power system • Undertake assessment of the existing or inherent power factor • Existing facilities – determine the existing power factor based upon metering data where possible • Proposed facilities – estimate the power factor based upon the types of electrical equipment to be installed as part the project • Establish target power factor, including alignment with regulatory required limits where relevant, or otherwise as defined by whole-of-life assessment that is commensurate in detail with the scale and scope of the installation Determine the size of power factor correction system required, and undertake cost / benefit analysis	☐ Functional Brief
Schematic Design	• Planning impacts, including: o Spatial requirements o Integration with existing or planned infrastructure o Required communications protocols to allow monitoring and recording Metering requirements of the site to allow ongoing monitoring of the installation's power factor	☐ Return Brief
Detail Design	• Product selections including rating & type (e.g., Capacitor vs solid state) • Number of steps to be incorporated into the power correction system if a capacitor-based system • Voltage • Correction Strategy including connection point in the distribution system (local to equipment or bulk correction at site intake) and determination of HV or LV equipment • Assessment of other correction methods (e.g., addition of VSD, upgrade of equipment, harmonic correction etc)	☐ Detailed Design Documentation, including: o Power factor correction calculations based on the inherent and target power factor o Single line diagrams demonstrating the integration of power factor correction with power systems ☐ Product specifications
Tender	• Require commentary on projected cost savings in tender documentation • Assess tender responses for projected cost savings • Specifically relates to Design & Construct style procurements where power factor correction may not be outright specified	☐ Tender evaluations
Construction	• Commissioning to be undertaken with consideration of energy efficient controls and operations	☐ Commissioning Report
Post Practical Completion	• Ensure power factor correction systems are not over-compensating and resulting in leading power factors • Routine maintenance	☐ Ongoing Maintenance Reports

7.3 Technical Details

The information presented in Table 7-2 expands on the energy efficiency considerations that are referenced in Table 7-1.

Table 7-2 Description of efficiency considerations for power factor correction

Efficiency Consideration	Description
WOL assessment	• Perform a whole a life (WOL) assessment during the preliminary design stage detailing energy efficiency considerations and feasibility for the project specific requirements. The electrical WOL assessment must include the following parameters as a minimum in the analysis: o Required statutory limits for power factor of installation o Price for demand (demand charges) o Traffic structure (peak/off-peak etc.) o Capital cost o Asset life o Operation & maintenance o A sensitivity analysis should be undertaken on the whole of life assessment with respect to the target power factor, particularly noting the scale and cost of power factor correction increases on a non-linear basis, proportional to the target power factor.
• Consider the value of incorporating power factor correction into a power system. • Undertake assessment of the existing or inherent power factor • Existing facilities – determine the existing power factor based upon metering data where possible • Proposed facilities – estimate the power factor based upon the types of electrical equipment to be installed as part the project • Establish target power factor • Determine the size of power factor correction system required,	• Many types of installations can operate effectively at power factor values less than unity. In Queensland, the statutory limits of operating power factor are established by the Electricity Regulation (Qld), National Electricity Rules (NER) and associated Energy Queensland (Energex / Ergon Energy) technical standards. At the time of writing, these limits are established in the Queensland Electricity Connection Manual (QECM): o Nominal supply voltage 50 kV – 250 kV (high voltage connections): 0.95 lagging to unity o Nominal supply voltage 1 kV – < 50 kV (high voltage connections): 0.90 lagging to 0.9 leading o Nominal supply voltage < 1 kV (low voltage connections): > 0.8 lagging to unity • Outside of these statutory limits, the operator of an installation may wish to further improve upon the inherent power factor of a system to drive energy efficient outcomes. Such outcomes can also contribute to savings in the cost of electricity supply. • In establishing a target power factor, an obvious target may be unity, as it represents the optimal operation of a power system. However, the determination should factor in whole of life aspects including ongoing maintenance costs, likely future load changes and utility cost savings. The designer should note that the scale and cost of power factor correction increases on a non-linear basis, proportional to the target power factor. That is, correcting power factor from 0.90 to 1.00 (as an example), requires more than double the scale of power factor correction, when compared to correcting from 0.90 to 0.95. • Target power factors above 0.95 are generally not economical.

Efficiency Consideration	Description
Planning impacts	• Defining what the planning impacts of the system are on the project, whilst not directly related to energy efficient outcomes, is a critical step to subsequently allow the specification of power factor correction systems within any constraints that may be present. • Designers should note that power factor correction should be installed downstream of any authority metering, in accordance with supply rules.
Product selections Number of steps to be incorporated into the power factor correction system	• The granularity to which a system can respond to load changes, impacts the effectiveness of the system achieving the target power factor: ○ For a capacitor-based system that is configured in multiple "steps", consider a 60 kvar PFC system. ○ For a load that requires correction of approximately 40kVA, a system that steps in increments of 20 kvar could provide correction of 40 kvar, and therefore achieve close to unity power factor ○ A system that steps in increments of 15 kvar could provide correction of 30 kvar, but not 45 kvar, as it would result in over-compensation, and a leading power factor which is not allowable under regulatory guidance. ○ In this example, a system with 20 kvar steps may be more appropriate. In other examples, systems with smaller steps may be more suitable. • The adoption of a stepless solid state system should also be assessed to determine whether the additional upfront cost is justifiable when it will better respond to dynamic loads and will likely require less long-term maintenance.

7.4 Additional Materials

Table 7.3 includes references to additional technical documentation concerning power factor correction.

Table 7-3 Supplementary materials supporting energy efficient power factor correction

Related Energy Efficiency Consideration	Document Publisher (Link)	Relevance
Various	EATON https://www.eaton.com/content/dam/eaton/products/low-voltage-power-distribution-controls-systems/power-factor-corrections/portfolio/eaton-pfc-guide-plant-engineer-SA02607001E.pdf	EATON have published a comprehensive technical article on Power Factor Correction (PFC).
Various	ResearchGate https://www.researchgate.net/publication/338793419_The_technical_and_economic_advantages_of_power_factor_correction	This academic publication, available via ResearchGate, presents an analysis of the technical and economic advantages of power factor correction.

7.5 Case Studies

7.5.1 Power Factor Correction for an Injection Moulding Business in Brisbane

Management for this medium-sized engineering facility felt that their electricity costs were too high and sought a solution that would pay itself back in three years or less. The merits of power factor correction (PFC) and solar power were investigated, however only PFC was implemented as it offers a reduction in kVA consumption irrespective of the time of day (or night) and local weather conditions.

Analysis revealed that the site had a ‘real’ (kW) demand for electrical energy of 500 kW and a power factor of 0.8. Improving the power factor will reduce the supply transformer requirements or increase the available ‘real’ power from the transformer.

By using the Sinexcel SVG Power Factor Correction Equipment, the power factor was improved to 0.99. The apparent power required to produce 500 kW of real power was reduced to 505KVA, which represented a saving of 120KVA. Overall, the installation achieved the following:

A reduction in electricity demand charges of $1,068 per month

A payback period of well under two years

Publisher: Fuseco

Source: Injection moulding business in Brisbane - Fuseco

7.5.2 Mackays Product Solutions Case Study

Mackays Produce Solutions (Mackays) provides consulting and storage services to tropical fruit growers. AGL proposed a solution for Mackays to improve the energy efficiency of their advanced, climate-controlled facility in Larapinta.

Alongside payroll, energy was one of the business’s largest expenses. Mackays determined that Power Factor Correction and lighting upgrades/improvements would each have a relatively short payback period and lead to significant cost savings over the long-term.

With the combination of Power Factor Correction and various lighting upgrades at the facility, Mackays reduced their total energy costs by $50,738 after just two and a half years.

Publisher: AGL

Source: Mackays Produce Solutions (agl.com.au)

8 Energy Efficient Lighting Systems

8.1 Overview

Lighting systems are a core component of all buildings, infrastructure, and other physical assets.

Adequate illumination in indoor and outdoor environments is fundamental to ensure tasks can be carried out safely, productively and without strain to the people in that environment. Whilst these priorities initially suggest that ‘more light is better light’, the control of artificial lighting is equally as fundamental to ensure solutions are efficient, non-obtrusive, environmentally sensitive and comfortable. Balancing these objectives requires lighting solutions that are both human centred and energy efficient.

Lighting systems are generally formed by the combination of:

- Artificial illumination provided by electric luminaires
- Contribution by natural daylight
- Lighting controls

In aggregate, lighting systems can account for a material proportion of a facility's total energy consumption. This section focuses on the methods, materials and operational interventions that can reduce the energy consumption of these systems while improving or maintaining lighting performance.

8.2 Efficiency Considerations

The following table outlines the processes and considerations that should be followed to determine energy efficient outcomes at each project phase.

These must be implemented by the relevant discipline in the project Design Team, the Sustainability Engineer/Consultant, and the Quantity Surveyor.

Table 8-1 Energy efficiency considerations for lighting systems

Project Phase	Consideration	Deliverable
Project Planning	Environmental considerations, including: o The functional requirements and style of tasks to be undertaken in each type of functional area o The physical details, furnishing and materiality of the space o The level of pedestrian / cyclist activity (exterior environments) o The fear of crime The need to enhance amenity	☐ Functional Brief
Schematic Design	• Consideration of target lighting technical parameters and limits established by classification of each type of functional area in accordance with the relevant Australian Standard (AS/NZS 1680 (set), AS/NZS 1158.3.1, AS/NZS 4282). • Consideration of the need to control the obtrusive effects of outdoor lighting in accordance with AS/NZS 4282, and subsequent additional target lighting technical parameters and limits. • Other lighting design considerations: o Lighting control zoning o Lighting control systems Daylighting opportunities	☐ Return Brief
Detail Design	• Selection of luminaires to achieve the target lighting technical parameters. • Design of lighting layouts to achieve the target lighting technical parameters.	☐ Lighting Options Report ☐ Detailed Design Documentation, including: o Lighting layouts o Lighting control zoning layouts o Lighting control functional description o Lighting control schematics ☐ Luminaire schedule
Tender	• Require commentary on energy efficiency in tender documentation • Where a specific set of luminaires and/or detailed design is not provided (i.e., under a D&C procurement arrangement), consider specifying minimum energy efficiency and performance requirements in Watts/m^2 or Watts/m^2/100 lux • Assess tender responses for energy efficiency	☐ Tender evaluations

Project Phase	Consideration	Deliverable
Construction	• Commissioning to be undertaken with consideration of energy efficient controls and operations • Ensure that lighting controls and other automated features have been installed as specified	☐ Commissioning Report
Post Practical Completion	• Ensure that equipment shut-down procedures are adhered to (e.g., for intermittently occupied facilities) • Routine maintenance	☐ Ongoing Maintenance Reports

8.3 Technical Details

The information presented in Table 8-2 expands on the energy efficiency considerations that are referenced in Table 8-1.

Table 8-2 Description of efficiency considerations for lighting systems

Efficiency Consideration	Description
WOL assessment	• Perform a whole a life (WOL) assessment during the preliminary design stage detailing energy efficiency considerations and feasibility for the project specific requirements. The electrical WOL assessment must include the following parameters as a minimum in the analysis: o Wattage o Duty (%) o Control strategy o Price of electricity o Price for demand (demand charges) o Tariff structure (peak/off-peak etc.) o Installed cost o Replacement costs o Lifetime
Environmental considerations	• Environmental considerations together define the criteria to allow spaces to be classified in accordance with relevant Australian or international standards. • The definition of environmental considerations, whilst not directly related to energy efficient outcomes, is a critical step to subsequently allow the energy efficiency targets for a lighting system to be established. • The classification of functional areas should be undertaken in accordance with the requirements of AS/NZS 1680 (set) for interior lighting applications, AS/NZS 1158.3.1 for most exterior lighting applications, or other relevant guidance available in Australian or international standards.

Efficiency Consideration	Description
Consideration of target lighting technical parameters and limits established by classification of each type of functional area in accordance with the relevant Australian Standard. Consideration of the need to control the obtrusive effects of outdoor lighting in accordance with AS/NZS 4282, and subsequent additional target lighting technical parameters and limits. Lighting design considerations: • Lighting control zoning • Lighting control systems	• Classification of functional areas in accordance with the relevant Australian or international standard allows lighting technical parameters and limits to be established. • The classification of functional areas, whilst not directly related to energy efficient outcomes, is a critical step to subsequently allow the energy efficiency targets for a lighting system to be established. • The classification of functional areas should be undertaken in accordance with the requirements of AS/NZS 1680 (set) for interior lighting applications, AS/NZS 1158.3.1 for most exterior lighting applications, or other relevant guidance available in Australian or international standards. • The classification of functional areas should also be undertaken in accordance with the requirements of AS/NZS 4282 for outdoor lighting applications, to subsequently establish lighting technical parameters to control the obtrusive effects of outdoor lighting. • Refer AS/NZS 1680 (set), AS/NZS 1158.3.1 and AS/NZS 4282 for relevant definitions and direction.
Lighting design considerations: • Lighting control zoning • Lighting control systems	• Lighting control zoning: The definition of zones in which luminaires will typically be controlled using the same lighting control methodology. The definition of lighting control zones permits groups of luminaires to be separately controlled. A lighting control zone that is too large may result in luminaires operating when they are not needed to provide task lighting, and subsequently in wasted energy. Conversely, a lighting control zone that is too small may result in peripheral annoyance, distraction, or discomfort to occupants due to luminaires regularly switching on and off. Section J6 of Volume 1 of the Building Code of Australia establishes limits on the size of lighting control zones for certain classes of buildings. Lighting control zones can be established in interior and exterior lighting applications. Adjustments to lighting control zones can be made to existing lighting installations. • Lighting control systems: A combination of user interfaces, such as lighting control panels and occupancy sensors, and control logic used to switch lighting on, off and between dimming levels in response to a variety of user inputs. Lighting control methodologies that include the use of occupancy, absence and/or time-based sensors achieve energy savings by switching lights on, off and between levels automatically. Occupancy, absence and time-based sensors can be used in combination with manual user controls to ensure illumination is provided in the appropriate form when light is required. Lighting control systems are traditionally used with interior lighting systems but can equally be applied to exterior lighting systems to achieve energy savings through automatic dimming when an area is not populated. Section J6 of Volume 1 of the Building Code of Australia establishes constraints for the type of functional lighting controls for certain classes of buildings. Lighting control systems can be established in interior and exterior lighting applications. Lighting control systems can be introduced to existing lighting installations. • Daylighting opportunities (Daylight harvesting): The use of daylight to supplement and/or replace artificial lighting to achieve lighting technical parameters. In combination with lighting control systems, daylight can be used (or ‘harvested’) in place of artificial light, and to achieve energy savings by allowing luminaires to be dimmed or switched off if sufficient natural light is available. Daylight harvesting can be established in interior and exterior lighting applications. Daylight harvesting can be introduced to existing lighting installations.

Efficiency Consideration	Description
Selection of luminaires to achieve the target lighting technical parameters, with consideration of: • Luminous flux • Luminaire efficiency • Luminaire source • Luminaire efficacy • Luminaire maintenance factor • Luminaire lifetime • Luminaire distribution • Upward wasted light ratio	• Luminous flux: The measure of the quantity of light emitted by a light source. The quantity of light emitted by a luminaire or luminaire source is its luminous flux. The total luminous flux of a complete luminaire may not be the same as the aggregate luminous flux of the luminaire sources, due to inefficiencies in the optics of the luminaire. This is especially true where luminaires use reflector-based technology due to inherent losses that occur when light is reflected. Luminous flux is measured Lumens. • Luminaire efficiency: The ratio of the luminous flux of the luminaire source to the luminous flux of the complete luminaire. • Luminaire source: The type of light emitting technology used within the luminaire. Since the adoption of Light Emitting Diode (LED) luminaire sources, the technology has expanded across applications and luminaire types, and is now incorporated into the vast majority of products on the market. The quality and adaptability of LED sources is such that very few applications are unsuitable for use with LED technology. The more efficient light sources also result in less wasted heat, therefore reducing load on the building's mechanical plant. Luminaires with LED sources have high efficacy and subject to quality of manufacture, can be controlled to minimise the total operating power of the luminaire. • Luminaire efficacy: A measure of how well a complete luminaire produces light energy. It is the ratio of the total luminous flux of the luminaire to power, measured in lumens per Watt. With improvement in LED technology, the efficacy of luminaire sources, and therefore also luminaires, has increased over time. In modern luminaires, an efficacy of between 100 – 150 lumens per Watt should generally be targeted. • Luminaire maintenance factor: A factor that accounts for losses in output over the lifetime of a luminaire. The maintenance of light technical parameters depreciates over time due to a number of factors including the Luminaire Maintenance Factor (LMF, describing the depreciation in luminaire output due to dirt and dust build up); Lamp Lumen Maintenance Factors (LLMF, describing the inherent nature of sources to depreciate in output); Lamp Survival Factor (LSF, describing the statistical probability a source will fail during its service life); and Room Surface Maintenance Factor (RSMF, describing the deprecation in light reflectance from room surfaces due to dirt and dust build up). Maintenance factors are used in calculations to account for depreciation over time, and to ensure calculated values reflect an end-of-life scenario. Light technical parameters are therefore typically exceeded upon initial installation. • Luminaire lifetime: The lifetime of a luminaire incorporating an LED source is derived from testing undertaken in accordance with ANSI/IES LM-80 and is forecast and expressed in accordance with ANSI/IES TM-21. The expected lifetime luminaire is expressed as "LxxByy @ zz,000 hours" where at zz,000 hours, at least yy% of the LED sources will be at xx% output, or above. A lighting installation comprised of luminaires with long lifetimes may not affect the operational electricity usage of that system, however does impact the amount of embodied carbon associated with a facility over its lifetime. • Luminaire distribution: The manner in which the luminous flux radiated by a luminaire is distributed in the various directions within the space around it. Luminaire sources such as LEDs typically radiate light energy in all available directions. The incorporation of a source into a luminaire is what defines the luminaire's distribution. Luminaires typically incorporate reflector- or lens-based technology to control the light energy radiated by a source into a specific distribution. General lighting luminaires will often incorporate very broad or non-specific distributions. In contrast, a luminaire that is designed for a specific application will often incorporate a tightly controlled distribution, such that light is delivered on to a specific surface in a very intentional manner. Lower quality luminaires that are marketed for specific applications may lack this tight control. In this sense, the efficiency of a lighting system is derived from more than simply the efficacy of the luminaires that make up the system. The efficiency of the system is also driven by the careful use of light energy, with higher efficiency systems focussed on illuminating task areas without incidental (wasted) light illuminating areas as an unintended consequence. • Upward wasted light ratio (UWLR): In exterior lighting systems, the ratio of 'wasted' light that is emitted above the horizontal towards the night sky, to the light that is used to illuminate useful surfaces. Light that is emitted above the horizontal towards the night sky not only contributes to sky glow, but also represents energy that is wasted as it does not contribute to functional or aesthetic lighting.

Efficiency Consideration	Description
Design of lighting layouts to achieve the target lighting	• Positioning of luminaires to achieve the target lighting technical parameters using the fewest number of luminaires. The resultant lighting layout should be compiled, using the selected luminaires, to achieve the lighting technical parameters using the fewest number of luminaires possible. This approach to lighting design will yield far greater energy savings than the combination of elements noted above.

8.4 Additional Materials

Table 8-3 includes references to additional technical documentation concerning lighting systems.

Related Energy Efficiency Consideration	Document Title (*Publisher*)	Description / Relevance
Various	**Equipment and Technology Guides / Lighting** *Department of Industry, Science, Energy and Resources*	The Australian Government's Department of Industry, Science, Energy and Resources has developed a range of equipment and technology guides to support Australian businesses.
Various	**Tenancy Lighting** *Australian Government Department of Climate Change and Energy Efficiency*	The Australian Government's Department of Climate Change and Energy Efficiency has produced a summary report regarding tenancy lighting. This report includes key lighting system terminology, energy efficiency opportunities, and case studies.
Various	**Energy Efficient Lighting** *Whole Building Design Guide*	The National Institute of Building Sciences (an American agency) has developed the Whole of Building Design Guide (WBDG). This guide functions as a gateway to up-to-date information on integrated 'whole building' design techniques and technologies.
Various	**Efficient Lighting Strategies** *U.S. Department of Energy*	The United States Department of Energy has developed a fact sheet concerning efficient lighting strategies. This document outlines the business case for integrating energy efficient lighting, as well as technologies and design recommendations to reduce energy consumption.
Various	**Erco Guide** *Erco*	The Guide section provides thorough information on everything from the physical bases of lighting to suggested solutions for concrete lighting situations an encyclopaedia of architectural lighting. The knowledge modules make use of the interactive possibilities offered by the Internet, e.g. for illustrating time-dependent phenomenon, experiments or contrasts between alternative solutions.
Various	**The Lighting Handbook** *Zumtobel*	This handbook provides a significant amount of information regarding key lighting concepts, characteristics, types, and opportunities (design and equipment) for maximising energy efficiency.

8.5 Case Studies

8.5.1 WT Sustainability no Compromises for a 6 Star Tenancy Fitout

WT Sustainability (WTS) are specialist sustainability consultants for the built environment. WTS took the opportunity, when fitting out their new office in North Sydney, to use in-house expertise and knowledge in integrating sustainable design and construction practice and initiatives.

To achieve their ambitious targets, WTS focused on the high-energy sources of consumption within the tenancy, including supplementary air conditioning, lighting, and office equipment.

A high level of lighting control was negotiated with the light fitting supplier, which allowed occupancy sensors to control lighting in zones of 30 m^2 or less. Other features include the dimming of lights to 50 per cent if no occupancy is sensed after five minutes. After a further five minutes, if no occupancy is sensed, the lights turn off. A ‘kill switch’ to turn off all lighting systems and their controls at the mains was installed next to the front door. A policy of ‘last one out turns off the lighting’ was introduced so the occupancy sensors weren’t operating and drawing power throughout the night when no one was in the office. All lighting is controlled by photoelectric cells, ensuring they turn off when there is adequate daylight. The office layout itself was also designed so that low height and glazed office partitions allow for as much natural daylight access as possible.

Annual energy savings owing to these initiatives (in addition to HVAC and equipment considerations) is estimated to be 23,800 kWh (25 tonnes of CO_2e), which equates to a cost saving of approximately $6,600 (compared to an ‘average’ office).

Publisher: CitySwitch

Source:
https://cityswitch.net.au/Portals/0/Case%20study%20pdfs/CitySwitch%20Case%20Study%20WT%20Sustainability%20final.pdf

8.5.2 University of Technology Sydney City Campus – Retrofit delivers increased energy efficiency

The existing lighting in the Ultimo Campus Building 10 fire stairs was an emergency double 36W T8 fluorescent fixture driven by magnetic ballast. The lights operated 24/7 and had no energy saving controls.

T8 fluorescent fixtures were replaced with Chamaeleon emergency lights, generating average lighting levels of 95 lux, which were above Australian standard AS1680 requirements of 80 lux.

Electricity consumption data logged by enLighten Australia indicated a 92% reduction in electricity usage across the fire stairs.

The Chamaeleon installation also resulted in an average 6% increase in power factor. Power factor improvements indicate improved operation in the lighting circuit and translates into future reductions in the electricity network provider’s kVA energy demand charge.

The estimated payback period for this intervention was estimated at 1.4 years.

Publisher: enLighten

Source: https://www.enlighten.com.au/case-study/university-of-technology-sydney-city-campus

8.5.3 Industrial Lighting – Dynamic Windows

Dynamic Windows manufacture a wide range of window and door products in Bairnsdale, Victoria. Their goal was to engage in a cost-effective project to reduce the facility’s energy consumption.

Engineers at Genesis Now undertook a thorough analysis of the lighting needs at the facility to model and deliver a customised LED solution with smart controls. The controls ensure that artificial lighting responds intuitively to available day light and activity without leaving pockets of darkness where staff might be required to work alone in large spaces. The business case was further improved by the lighting design, which reduced the light count significantly whilst increasing brightness for all areas to exceed Australian Standards.

The project is expected to reduce this business's energy consumption by 175 MWh per annum, with an estimated payback period of 3 months.

Publisher: Genesis Now

Source: https://genesisnow.com.au/wp-content/uploads/2018/07/Dynamic-Windows-Lighting-Case-Study.pdf

9 Variable Speed Drives (VSDs)

9.1 Overview

The basic function of a Variable Speed Drive is to vary the speed (frequency) of a motor and control how the motor operates.

A VSD controls the speed and torque of an AC motor by converting fixed frequency and voltage input to a variable frequency and voltage output. System performance can be greatly improved by controlling the speed to precisely match the load and allowing a motor to operate over a broad range.

Efficiency values for motor drive systems when connected to various loads can usually be obtained from equipment manufacturers. VSD's can optimise variable motor system operation, reduce maintenance costs, reduce wasted energy and reduce ambient noise emissions by allowing the connected equipment to operate at variable duty points as opposed to operating continuously at a speed greater than the desired demand profile.

VSD's can suffer from inherent losses and are therefore not as energy efficient as independent electronic controls and may not be suitable for fixed speed systems.

At Seqwater, VSD's are primarily used for the electric motors serving pumps.

9.2 Efficiency Considerations

The following table outlines the processes and considerations that should be followed to determine energy efficient outcomes at each project phase.

These must be implemented by the relevant discipline in the project Design Team, the Sustainability Engineer/Consultant, and the Quantity Surveyor.

Table 9-1 Energy efficiency considerations for use of VSDs

Project Phase	Consideration	Deliverable
Project Planning	• Identify systems where VSD's could be incorporated into the design	☐ Detailed Business Case
Preliminary Design	• Define the systems which include electric motors delivering variable loads and analyse where the use of VSD's would be appropriate based on a cost benefit analysis. • WOL assessment	☐ Preliminary Design Report ☐ WOL Report
Detail Design	• Energy savings • Installation	☐ Detail Design Report – Including section on energy efficiency
Tender	• Assess Tender responses for energy efficiency implementation	☐ Tender Evaluations
Construction	• Installation as per design and manufacturer requirements • Review of commissioning results for correct operation	☐ Inspection Reports ☐ Commissioning Reports

Project Phase	Consideration	Deliverable
Post Practical Completion	• Monitoring of system operation • Site tuning process to include review of VSD performance • General maintenance	☐ Ongoing Maintenance Reports

9.3 Technical Details

The information presented in Table 9-2 expands on the energy efficiency considerations that are referenced in Table 9-1.

Table 9-2 Description of efficiency considerations for VSDs

Efficiency Consideration	Description
WOL assessment	• Perform a whole a life (WOL) assessment during the preliminary design stage detailing energy efficiency considerations and feasibility for the project specific requirements. The variable speed drive (for pumps) WOL assessment must include the following parameters as a minimum in the analysis: o Capital cost o Ongoing cost o Annual power consumption o Net payback period o Motor size o DOL/VSD o Load factor o Power factor o Duty % o Price of electricity o Price for demand o Tariff structure (peak/off-peak etc.) o Asset life o Operation & maintenance o Pump performance curve o Best efficiency point o System curves o Pump power curve o Required flow rates

Efficiency Consideration	Description

Energy savings	• Variable speed drives can save significant amounts of energy when paired to an appropriate application where variable motor speed operation is required. By allowing the speed to be varied and accurately controlled, the motor does not need to run at full capacity and therefore the speed of the motor can match the demand of the system leading to an overall reduction in energy usage.
	• By controlling the speed of motors, in particular for pumping systems, the system flow rate can be controlled by the pumps as opposed to manual or motorised valves, therefore reducing wasted energy and increasing energy efficiency of the system.
	• Variable speed drives can also be fitted to motor systems to reduce the maximum power draw, provide accurate control of pressure and flow, reduced equipment noise levels and be integrated with a Building Management System for control and tuning.
	• Perform a cost benefit analysis for VSD implementation for the specific application and detail the findings in the WOL report.
	• Consider implementation of variable speed drives in combination with high efficiency motors for all systems requiring variable speed operation including fans for ventilation and air-conditioning systems, pumping systems, compressors and blower systems.
	• To estimate energy savings when a VSD is applied to a variable or constant torque load, determine:
	  ○ The lengths of time the equipment operates under various load conditions.
	  ○ The efficiency of the potential VSD and motor combination when operating in comparable situations.

Installation	• The ambient temperature where the drive is installed should be kept below the manufacturers requirements to prevent loss of performance from the drive. • Consider providing plantroom mechanical ventilation or air-conditioning to ensure optimal VSD operation. ○ If specific drives are subjected to higher ambient temperatures of over 45°C, then derating of the drives may be required, leading to an overall loss of efficiency or the need to install a larger capacity drive for the rated load.

9.4 Additional Materials

Table 9-3 includes references to additional technical documentation concerning variable speed drives (VSDs).

Table 9-3 Supplementary materials concerning use of VSDs for energy efficiency

Related Energy Efficiency Consideration	Document Title (Publisher)	Relevance
Various	Australian Government – Department of Industry, Science, Energy and Resources https://www.energy.gov.au/business/equipment-and-technology-guides/motors-and-variable-speed-drives	Government business advice which provides information on the use of VSDs for reducing business costs.
Various	ABB https://global.abb/group/en	VSD manufacturer providing information on appropriate use, installation and maintenance as well as benefits of VSD installation.
Various	Fantech https://www.fantech.com.au/AncilRange.aspx?RangeID=41	Fan supplier VSD advice and selections from Fantech range.

9.5 Case Studies

9.5.1 Fitting of Water Pump Motors with Variable Speed Drives

A series of water pumps run approximately 8,000 hrs. p.a. and are driven by ten 11kW high efficiency motors which are due for replacement. The motors run at full speed and pump flow is controlled via a throttling valve. The owner has the option of like-for-like replacements or purchasing high efficiency motors together with VSDs to control flow and achieve energy savings when speed is reduced.

A flow schedule analysis indicates that the VSD pumps would run at[2]:

- 100% speed, 20% of the time (1,600 hrs. p.a.)
- 75% speed, 50% of the time (4,000 hrs. p.a.)
- 50% speed, 30% of the time (2,400 hrs. p.a.)

The annual cash flows comprise the following:

- In the first year, the cost of installing the equipment
- In all years, the operating costs (including operation and maintenance, plus electricity costs) and the tax impact of purchasing the equipment.
- An electricity rate of $200/MWh in year one increasing each year by 2% (excluding inflation)

The company used these annual cash flows to calculate the following NPVs of installing each system.

- Standard System = -$944,835
- Comparatively Energy Efficient System = -$628,144
- Difference $316,691

The company determined that it would be better off by approximately $317,000 over 15 years if it invested in the energy efficient system.

Even though the energy efficient system is more expensive to install, it results in much lower electricity costs and lower operation and maintenance costs throughout its life. Based on this financial analysis, the company chooses to install the energy efficient system.

Author/Publisher: New South Wales Government – Department of Planning and Environment

Source: https://www.environment.nsw.gov.au/resources/business/financing-case-study-7.pdf

9.5.2 Wellington ONTRACK Substations

Eleven 7.5kW Siemens variable speed drives (VSDs), as well as a large quantity of active room sensors and controllers, were supplied for the ventilation control of the new substations along the Wellington railway system.

A temperature sensor directly connected to the VSD will modulate the duty fan's output based on the cooling demand. A second temperature sensor connected to a Siemens RWD82 controller initiates the emergency stand-by fan if the duty fan faults or cannot keep up with the cooling demand. Temperature run and fault signals are provided to the On-Track SCADA system.

Project engineers carried out onsite commissioning to ensure that the systems were operating as intended. The energy savings associated with this system (compared against a comparable system without VSDs) are predicted to be significant.

Author/Publisher: Setpoint Solutions

Source: Variable Speed Drives |Setpoint

[2] In practice, this analysis should also consider changes to the system curve from removing the throttling valve and changes in the pump curve by using the VSD.

10 Solar Photovoltaic (PV) Systems

10.1 Overview

Solar Photovoltaic (PV) systems are a widely used renewable energy generation technology that utilises the Sun's radiation to produce electrical energy. In simple terms, PV systems consist of multiple PV panels (also called modules), an inverter (or multiple inverters) and other electrical and mechanical hardware. Seqwater may investigate grid-connected or standalone PV systems paired with batteries, with the intent of predominantly using the power to offset operational consumption from the grid. In addition to any long-term financial benefits that solar PV projects deliver, they can contribute towards decarbonisation targets which the business may strive to achieve.

It is important to implement these PV systems according to a sound project development pathway to maximise the project benefits across the wide range of potential system sizes and energy supply applications. This chapter outlines decision points which should be considered in the project development of PV systems and provide a project development pathway that aligns with the Seqwater gateway process for general project planning, development, and delivery. In the context of Seqwater's project development processes, a PV system can be developed as an independent project or delivered as a component of an existing or new larger project, as discussed further below in Section **Error! Reference source not found.**.

10.2 Project Considerations

Seqwater's asset base consists of various asset types, which include, water treatment plants, pump stations, chemical dosing facilities, recreational areas, dams and reservoirs. Among the wide range of asset types, opportunities are presented for solar PV implementation in a variety of PV mounting types such as rooftop, ground mount (fixed tilt or single axis tracking systems), carpark canopies and floating solar PV (FPV). The PV module mounting structure design detail should be considered in the early stages of a project development for the optimum solution i.e., Seqwater Gateway 1 or 2. These include design attributes such as single axis tracking versus fixed tilt (for ground mount and potentially FPV systems) which require consideration in the context of the selected site and conditions.

Some of Seqwater's electricity loads may present opportunities for deferring electricity consumption to solar generation hours, which is advantageous for PV system development as it allows for the direct consumption of the system's energy output to be maximised. Seqwater may also wish to consider systems integrating batteries for remote locations or for sites subject to particularly high electricity or grid-connection costs. It's worth noting that hybrid solar/battery systems will become more financially attractive in a broader range of contexts as battery costs continue to decline.

10.2.1 Independent PV Project

Typically, PV projects are executed in phases, concept development, prefeasibility study, feasibility study, design, construction, and commercial operation. The phased execution does increase expenditure but reduces project risks and uncertainty to determine the optimal solution both technically and commercially. Some crucial considerations to be made in PV project development and interconnections of these considerations are captured in figure 10-1. It should be noted there are iterations in the process indicated below and many feedback loops from one consideration to the other to reduce said project uncertainty and risk.

CONSIDERATION 1

Defining clear project objectives

- Objectives such as power supply replacement, cost savings, decarbonisation targets, deferment of grid upgrades, etc.

CONSIDERATION 2

Site Assessment

- Identifying potential sites and space available
- Selection of site areas such as building or other rooftops, ground areas, water tanks, dam catchments or a combination
- Identifying grid connection potential and limitations at site
- Specialist studies required i.e. wind assessments, glint and glare assessments, wave and wake studies, etc.

CONSIDERATION 3

Energy modelling

- Defining the PV plant size and arrangement
- Considerations of loads, network power factor and other limitations i.e. export permitted, suitable area, etc.
- Grid connection or off-grid system
- Flexible / deferrable loads
- Energy yield assessments and cost optimisations
- Possible system types

CONSIDERATION 4

Technical design development

- Design development
- Inverter selection i.e. string or central or microinverters
- PV mounting option(s) selection i.e. ground mount (SAT or fixed tilt), rooftop, carpark canopy, FPV or a combination
- Permits, approvals and environmental considerations
- Power system modelling requirements
- Connection to the site network

CONSIDERATION 5

Planning and approvals

- Environmental and development approvals
- Other permit requirements
- Proximity to roads and airports (visual ammentiy, glint and glare)

CONSIDERATION 6

Grid connection

- Aggregate sizing confirmation from NER/AEMO, NSPs (size thresholds and basis for sizing)
- Application for STC or LGC
- Hyrid system considerations i.e. solar and BESS or pumped hydro, etc.
- Specialist power system modelling requirements i.e. inclusive of transient modelling based on the AEMO/DNSP requirements
- Testing i.e. Hold Point, etc.

CONSIDERATION 7

Off-grid systems

- PV connected with other generation i.e. diesel or energy storage i.e. BESS, etc.
- Microgrids of PV and energy storage, enabling other services i.e. load shifting, increased network capacity, demand management, etc.
- Identifying constraints
- Power system reliability (targeted availability, redundancy, power quality)

Figure 10-1 PV Project Development consideration and linkage

Table 10-1 outlines a high-level list of PV project development deliverables that can be considered up to financial approval stage. This provides further guidance to what is discussed above.

Table 10-1 Checklist of PV Project Development Deliverable to Financial Approval [3]

	Project development deliverables
☐	Detailed site plan development
☐	Assessment of solar resource and environmental characteristics
☐	Assessment of shading (horizon and nearby buildings and objects)
☐	Outline layout of areas suitable for PV development
☐	Assessment of technology options providing cost/ benefit for the project location
☐	Selection of module type and mounting system(s)
☐	Selection of inverter type and sizing
☐	System design development
☐	Identification and preliminary application for planning permits and other approvals
☐	Grid connection – identify requirement, detailed assessment of likelihood, cost and timing or assessment of standalone system with energy storage i.e., Battery Energy Storage System (BESS), etc.
☐	Energy yield assessment
☐	Financial modelling (including cost benefit analysis)
☐	Preparation and submission of the permit applications for the proposed solar PV project. These include (but not limited to) the following permits: • Planning • Developmental • Environmental • Operational works permits for earthworks, roadworks or other construction engineering activities
☐	Preparation and submission of a preliminary grid connection application
☐	Revision of the prefeasibility design and permits applications submitted previously
☐	Develop contracting and procurement strategy (turnkey EPC contract or multi- contract). Include O&M strategy (if required for sizable PV plants)
☐	Development of all documentation necessary for business case
☐	Supplier(s) tender package(s) development and issue (if required)
☐	Tender evaluation, contractor selection and ranking
☐	EPC tender documentation development and issue
☐	EPC contractor selection and ranking
☐	Contract negotiations and award
☐	Completion of a bankable energy yield assessment
☐	Financial model development covering the full life cycle of the plant
☐	Completion of a project risk analysis

[3] A. Miller and B. Lumby, *Utility Scale Solar Power Plants - A Guide for Developers and Investors*, 1st ed. New Delhi: International Finance Corporation (World Bank Group), 2012, p. 6.

	Project development deliverables
☐	Environmental impact assessment
☐	Detailed project report development
☐	Business case development

10.2.2 PV Project Co-deliverance with another Project

There are multiple ways a PV project can be developed in Seqwater's planning stages; via an independent venture or as a part of a larger project which can be either an existing project progressed within the master plan of projects or new. It should be noted for any existing larger projects, PV system co-deliverance should make financial sense. Figure 10-2**Error! Reference source not found.** indicates the point at which a PV system should ideally be considered when delivered as part of a larger existing project (i.e., prior to the Gateway 1 – development of the preliminary business case). However, it may be possible to introduce a PV development at other points in this process as well.

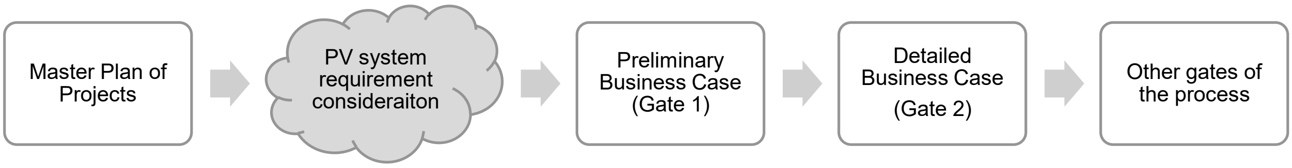


Figure 10-2 PV System development within larger projects

When seeking opportunities for development of solar PV plants across Seqwater's asset base, the options detailed in Table 10-2 should be explored.

Table 10-2 PV project opportunities

PV Project Type	Options to explore
General	Any government grants, incentives, and/or rebate programs for solar PV implementation
Independent PV projects	Sites with significant energy consumption where solar PV implementation could reduce long term energy costs (OPEX) and/or a solar/battery hybrid system could be considered
	Sites with significant variations in peak and off-peak rates and correlated consumption
	Sites with significant PV generation potential and convenient point of grid connection, where any excess power generated can be sold to the grid at a competitive price point
	Sites with PV energy generation potential (i.e., large potential for PV system size) to offset a significant amount of operational consumption
	Sites identified with vacant areas of space deemed suitable for solar PV implementations such as land, rooftop areas, carparks, dam reservoirs, etc.
	Sites that require additional energy security, especially at times of PV generation and high operational consumption (e.g., sites located in areas of existing grid instabilities and/or congestion at these times with site loads being a contributing factor)
PV systems implemented with other projects	Decarbonisation targets and/or emissions reductions set by the business and PV implementation considerations as a part of these projects

PV Project Type	Options to explore
	Major projects where a PV implementation is deemed feasible, and the project's economic analysis indicates solar PV to be a desirable investment compared to long-term traditional energy purchase arrangement (from the grid)
	Roof upgrade/renewal projects taking place should at a minimum account for possible future solar PV implementation
	Other renewable projects (i.e., BESS, traditional hydro, pumped hydro or wind), which indicate increased commercial value executed with solar PV

10.3 Project Development

As a PV project progresses through the planning process according to Seqwater's delivery gateways, the technical design of the project will evolve, particularly as additional details emerge through specialist studies (such as environmental, civil, structural, electrical and grid connection), as shown in Figure 10-3.

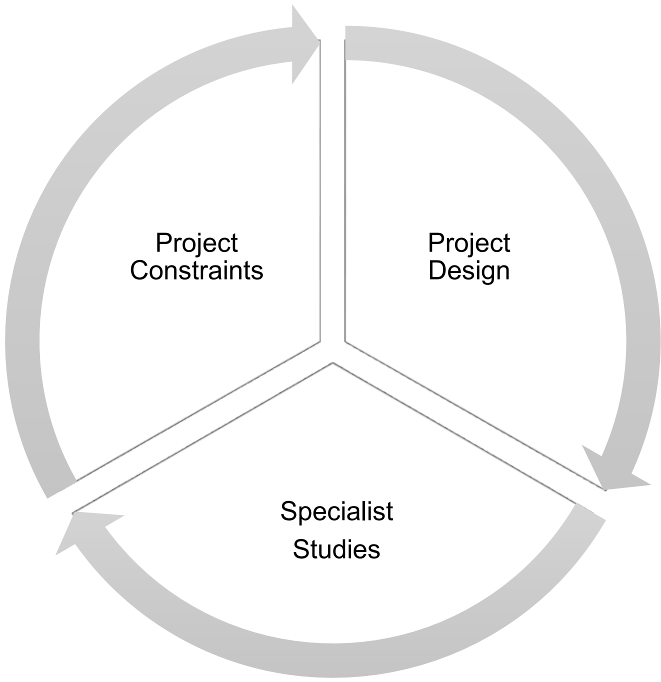


Figure 10-3 Interdependencies of Project Development

Figure 10-4 details the PV system project development process and alignment with Seqwater's Gateways. The x-axis (horizontal) represents time in the development pathway and y-axis (vertical) represents flexibility in adapting the optimal solution (commercially and technically), which declines as the developmental process advances towards Gateway 4.

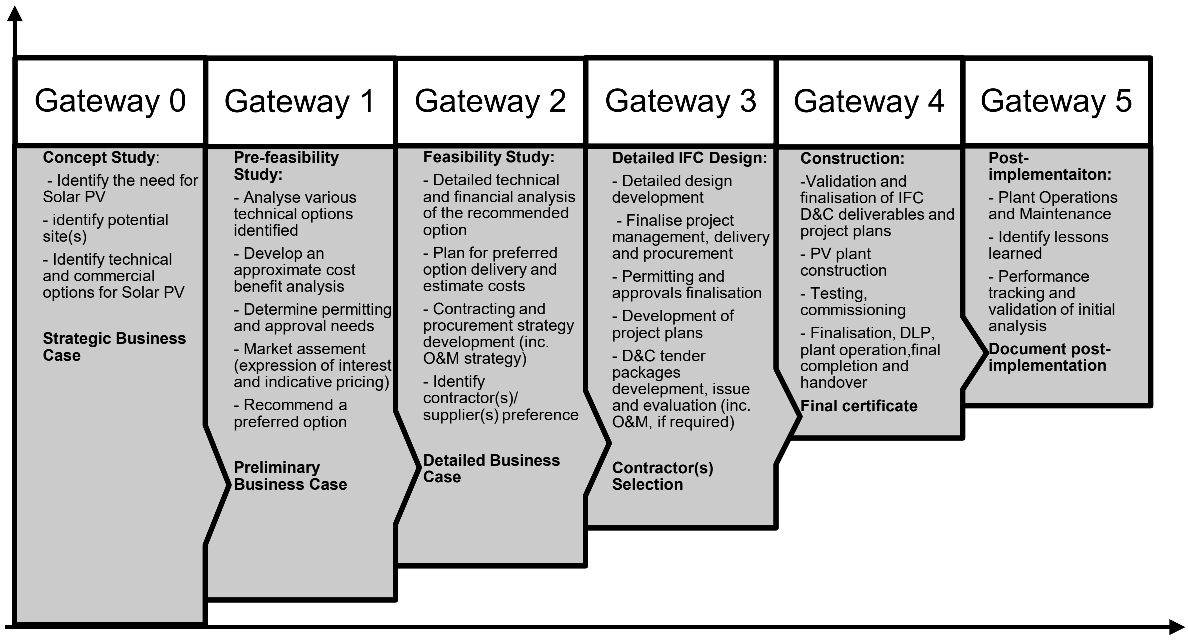


Figure 10-4 PV system development process, aligned with the Seqwater Gateway Process

In the early stages of project planning and development (from Gateway 0 to 1), it is important to explore and compare the full range of possible technical solutions (i.e., different types of PV systems as well as technologies other than solely PV). This should include consideration of potential government grants (if projects are commercially large enough) and various commercial arrangements for project revenue such as participation in energy markets or Power Purchase Agreements (PPAs). Moving into Gateway 2 and 3 stages, the focus should shift to refining and optimising the final technical design solution, where there is flexibility to do so prior to construction.

During the general project gateway stages indicated in Figure 10-4, the iterative process presented in Figure 10-3 needs to be managed carefully to ensure that effort is focussed on areas which will drive the project design towards implementation of the final, optimum technical solution with minimum project risks, uncertainty and oversight. For instance, any specialist studies performed as a part of the project, provides the opportunity to identify critical components that may otherwise be overlooked, which can be incorporated as a result of the process indicated in Figure 10-3.

The project development items to reach financial approval (from Gateway 0 to 2) are indicated in Figure 10-1.

Seqwater gateway process presented in with alignment to PV projects, should be used to guide the key decision points as each of these studies are completed. Gateway 4 captures the construction process, while Gateway 5 captures a pathway for review of the project to guide future development.

10.4 Technical Development

Refer to the Seqwater Solar PV Design and Construction Standard Specification for technical details for PV systems. This standard specification would ideally be used in Gateway 3.

11 Glossary

Acronym - Extension	
AIRAH	Australian Institute of Refrigeration, Air conditioning and Heating
BESS	Battery Energy Storage System
BMCS	Building Management and Control System
BMS	Building Management System
EC	Electronic Commutation
EEM	Energy Efficient Manual
EERE	The Office of Energy Efficiency and Renewable Energy
EPC	Engineering, Procurement, and Construction
FPV	Floating Solar Photovoltaic
GBCA	Green Building Council of Australia
HV	High Voltage
HVAC	Heating, Ventilation, and Air Conditioning
IEEE	Institute of Electrical and Electronics Engineers
LSF	Lamp Survival Factor
LV	Low Voltage
NCC	National Construction Code
NPSH	Net Positive Suction Head
NPV	Net Present Value
NSW	New South Whales
PFC	Power Factor Correction
PV	Solar Photovoltaics
PVC	Polyvinyl Chloride
QECM	Queensland Electricity Connection Manual
REC	Renewable Energy Certificate
RET	Renewable Energy Target
SHGC	Solar Heat Gain Coefficient
ULR	Upward Light Ratio
VAV	Variable Air Volume
VRF	Variable Refrigerant Flow
VSD	Variable Speed Drive
WOL	Whole of Life
WWR	Window Wall Ratio

12 Appendices

Refer D19008-4031-0001F Summary Report: Energy Efficiency Governance, authored by EfficientSee Pty Ltd June 2020.