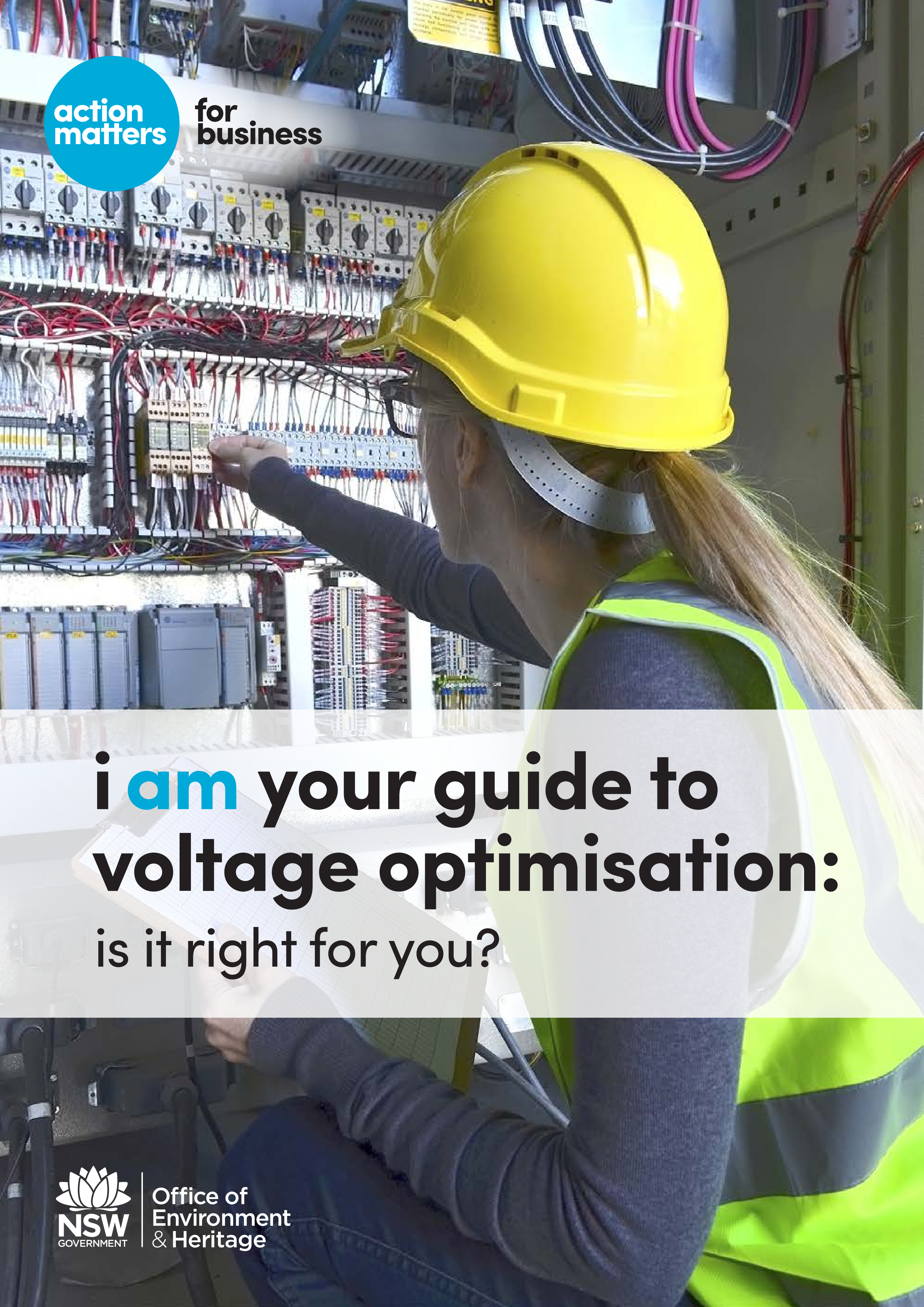

action matters for business

i am your guide to voltage optimisation:

is it right for you?

NSW GOVERNMENT

Office of Environment & Heritage

OEH has a panel of specialists who will be able to assist with any optimisation project.
Visit **www.environment.nsw.gov.au/business/energy-efficiency-expert.htm**

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Contents

Foreword

This publication has been developed by the NSW Office of Environment and Heritage's (OEH) Energy Efficient Business team with input from suppliers, industry bodies and energy specialists from across Australia.

OEH provides assistance to NSW businesses to reduce energy consumption and costs, while enhancing productivity. Technology guides like this publication aim to assist businesses in their decision-making. These guides, which include resources on lighting, industrial refrigeration, HVAC and cogeneration, are free to download from the OEH website: www.environment.nsw.gov.au/business/energy-efficiency-guides.htm

This publication would not have been possible without the contribution from SMEC Australia.

List of acronyms and abbreviations

AC: alternating current

CAPEX: capital expenditure

ECM: energy conservation measure

ESC: Energy Savings Certificate

ESS: Energy Savings Scheme

GHG: greenhouse gas

HIDL: high-intensity discharge lamp

HVAC: heating, ventilation and air-conditioning

IPART: Independent Pricing and Regulatory Tribunal

IT: information technology

LED: light-emitting diode

M&V: measurement and verification

OEH: NSW Office of Environment and Heritage

OPEX: operating expenditure

PIAM&V: project impact assessment with measurement and verification

PM: permanent magnet

TCO: total cost of ownership

UPS: uninterruptible power supply

VFD: variable frequency drive

VSD: variable speed drive

VVVF: variable-voltage, variable-frequency

Introduction

Voltage optimisation is just one of many solutions available to NSW businesses to help better manage both their energy and equipment assets. The voltage requirements for your site will largely be determined by the equipment you operate. For certain loads, reducing voltage can reduce the power consumed.

There are different types of voltage management techniques and technologies available in Australia. These could potentially help you not only achieve energy savings, but improve the life of your equipment as well.

Suppliers of different voltage optimisation technologies often quote energy savings attributable to their product. However, the ability of your site to achieve energy savings from voltage optimisation technologies can vary widely depending on your voltage supply and the type of equipment you power (Table 1 on page 2 and **Toolkit 1** on page 71).

For a site where a large proportion of equipment is considered to be sensitive to changes in voltage, it is possible to achieve anywhere up to 12% energy and greenhouse gas (GHG) savings. Some sites (including a case study in this guide) have observed savings above this figure, while others have on occasion seen limited energy savings – it really is site specific. In some instances, upgrading your equipment and processes on site may be more cost effective in the long term than voltage management, so be open to alternatives. As a decision-maker within your business, it's important to consider all aspects of any investment decision relative to your operations.

This guide will help you to determine whether this technology is suitable for your site operations, including:

- providing a clear and simple framework for making decisions about whether to invest in voltage optimisation at your site
- understanding the basics of voltage optimisation
- understanding the potential benefits and impacts of voltage optimisation.

In most cases, detailed investigations by suitably qualified and experienced specialists will be required. These investigations typically take time, cost and effort, so it is important to be confident in your decision that voltage optimisation is a good fit for your site before you get started on a detailed feasibility assessment.

Table 1: Summary of common voltage sensitive and non-sensitive equipment

Equipment type	Voltage sensitivity
Incandescent lamps	✓
Fluorescent lamps (inductive ballast)	✓
Fluorescent lamps (electronic ballast)	✗
Fluorescent lamps (high frequency)	✗
High intensity discharge lamps (inductive ballast)	✓
Induction lamps	✗
LEDs	✗
Motors: linear (fixed)	✓
Motors: permanent magnet	✗

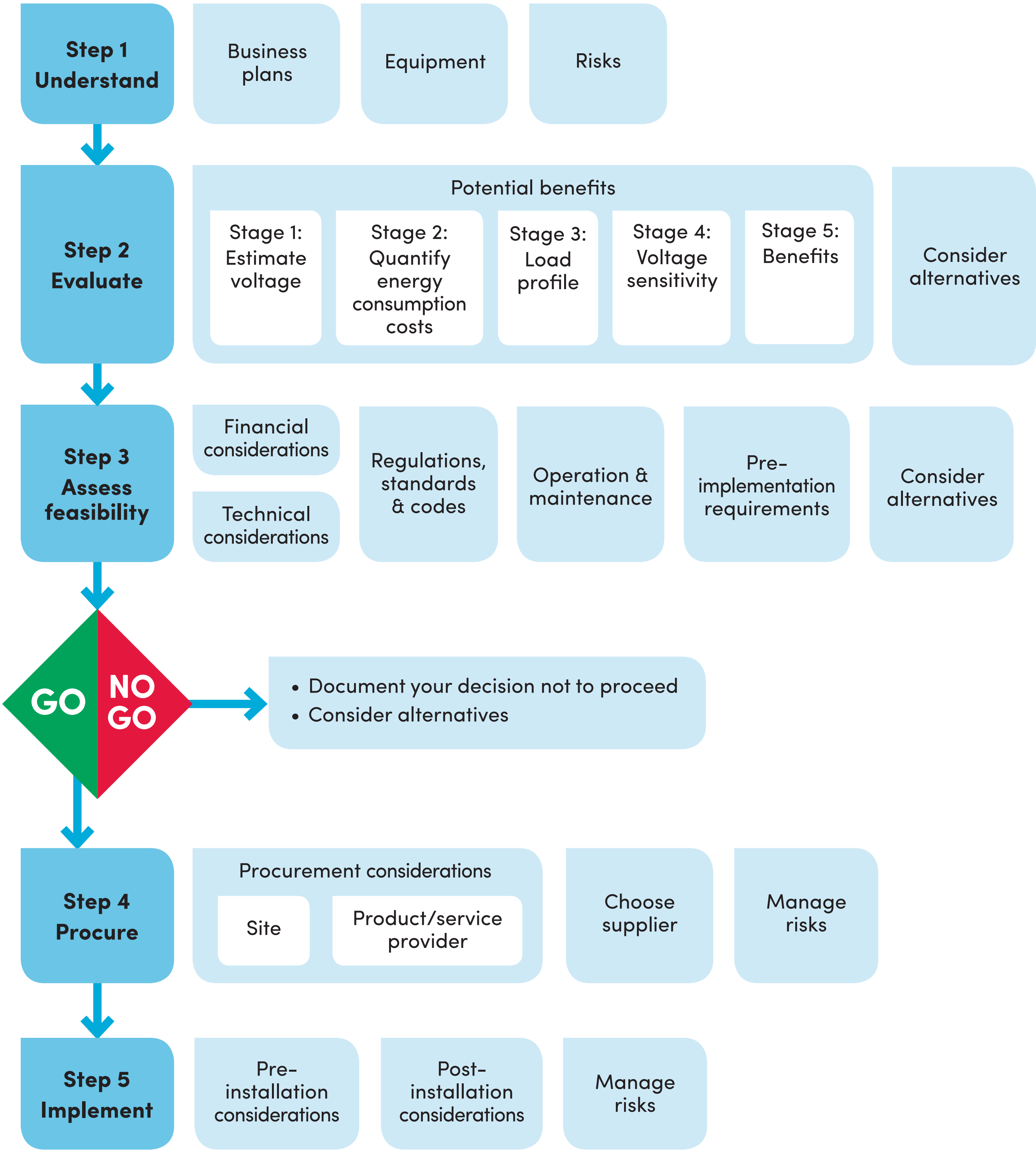
Equipment type	Voltage sensitivity
Motors: variable speed	?
Refrigeration (uncontrolled)	✓
Refrigeration (controlled)	?
HVAC (flow controlled)	✓
HVAC (flow uncontrolled)	✗
Heating: coil/resistance	✗
IT equipment	✗
Uninterruptable power supply (UPS)	✗
Equipment with inverters (surge protection)	✗

How to use this guide

This guide has three main sections:

1. **A step-by-step decision-making section** to help you work out the possible benefits and impacts of voltage optimisation at your site. Figure 2 outlines the process you will go through in working this out
2. **Appendices** that go into more detail on general voltage concepts and the principles behind voltage optimisation
3. **A toolkit** of checklists and document templates that will assist you as you go through the five steps of deciding whether voltage optimisation is right for you.

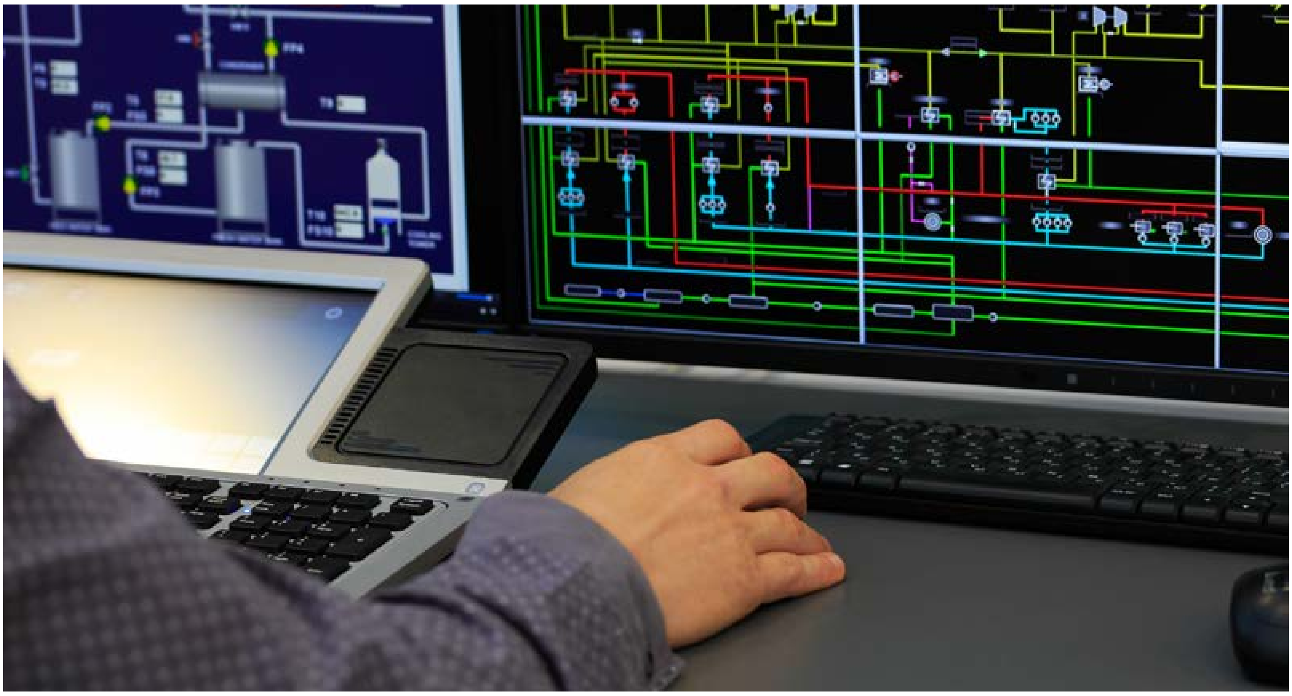
Figure 2: Flow chart of steps used in the decision-making guide to decide whether voltage optimisation is suitable for your site



one

Decision-making guide

This section takes you through the five steps of deciding on and implementing voltage optimisation, as outlined in Figure 2. You need to understand and work through each of these elements before choosing to go ahead.



Step 1: Understand

Step 1 Understand | **Step 2 Evaluate** | **Step 3 Assess feasibility** | **Step 4 Procure** | **Step 5 Implement**

- Business plans
- Equipment
- Risks

Step 1 aims to take you through the preliminary things you need to know to determine the suitability of voltage optimisation. At the completion of this step you will be able to make a confident decision on whether to allocate time and resources to further evaluate this technology.

Tip

Understanding your site is critical to making an informed and confident decision about the suitability of voltage optimisation. Because of the investment you need to make in the full decision-making process (i.e. evaluation, assessment, procurement and implementation), you should understand the following:

- key stakeholders
- the electricity-consuming equipment on site and its voltage sensitivity
- the issues, benefits and suitability of the investment
- business needs, drivers and plans.

Understanding your business plans

Considering your business and site plans will help you to understand the appropriateness of voltage optimisation. This is because your business' short, medium and long term plans will ultimately impact the suitability, cost and payback of voltage optimisation at your site. As part of this process, you should consider the elements in Table 2 very carefully.

Table 2: Understanding your business plans

Element	Key considerations
Business drivers	• business drivers behind considering voltage optimisation (e.g. cost reductions, energy savings) • financial expectations or hurdles (e.g. payback period, return on investment)
Site plans/strategies	• the current situation of your site (e.g. owned or leased premises) • the medium and long-term strategies (e.g. life of business) • planned activities (e.g. upgrades, expansions, developments, decommissioning) • foreseeable changes to operations and productivity
Energy consumption/ management	• current and future energy management/energy efficiency activities • potential power quality issues on site (e.g. overvoltage, voltage variations) • potential/expected benefits of voltage optimisation (this can be qualitative) • alignment of voltage optimisation to other activities at your site (e.g. equipment upgrades)
General operational and maintenance considerations	• equipment maintenance and replacement frequency (including associated costs) • known issues associated with your site's electrical infrastructure

Understanding your electrical equipment

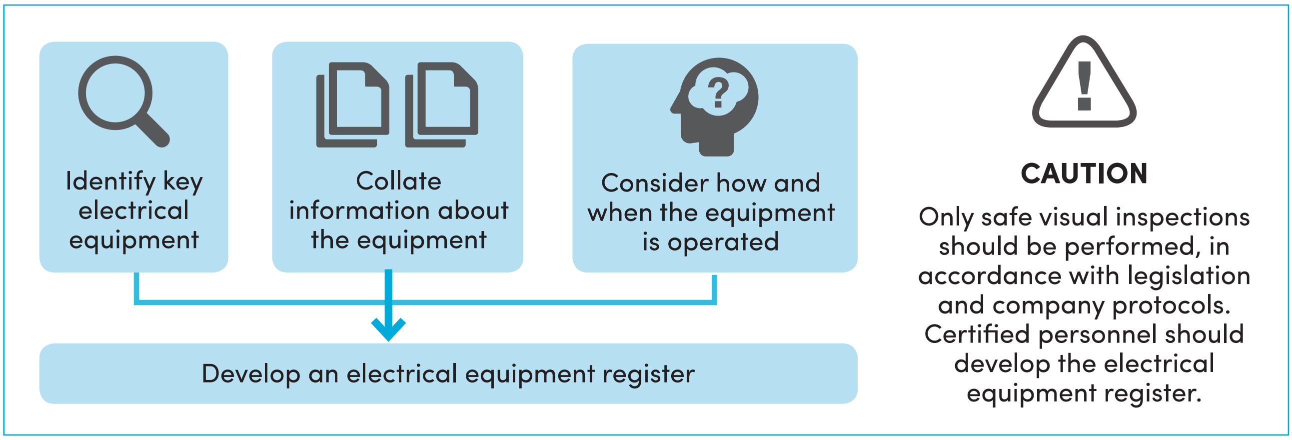
When considering the appropriateness of voltage optimisation, you should understand the specific characteristics and features of your electrical equipment. Without this understanding, estimating the benefits of voltage optimisation can be difficult and uncertain. This section will help you to:

- identify and collate relevant information about your electrical equipment to develop a register
- understand the voltage sensitivity of your equipment
- understand the electricity consumption profile of your site.

Identify and collate information to develop a register

You should develop a register of your key electrical equipment. This should include the simple steps in Figure 3.

Figure 3: Steps to developing a register of electrical equipment



The asset register should include, for example:

- the type of equipment
- number of units
- nameplate information, such as:
  - manufacturer
  - age (including installation date, refurbishment (if applicable), maintenance log)
  - power ratings (kW) and voltage ratings (V)
  - equipment utilisation rates (e.g. the percentage of time for which the equipment operates over a given period of time).
- voltage sensitivity (see the voltage sensitivity checklist in Table 5, as well as 'understanding your equipment's voltage sensitivity' on the following page)
- other information such as:
  - the role of the equipment (e.g. primary or standby pumps, general lighting, security lighting, uninterruptible power supply)
  - the equipment's replacement or upgrade dates (e.g. maintenance plan)
  - the criticality of the equipment (e.g. to determine the potential impact on operations should anything go wrong as a result of changes to site voltage)
  - any unique characteristics of the equipment (e.g. variations in how it operates under different production scenarios, seasonality requirements, etc.)

Understanding your equipment's voltage sensitivity

After the identification of the electrical equipment at your site, you should perform a high-level voltage sensitivity assessment. Categorise your equipment using **Toolkit 1** into either:

- **voltage-sensitive equipment:** power consumption and output of the appliance varies depending on the voltage supplied
- **voltage-non-sensitive equipment:** appliances are designed to have a fixed power consumption and output, irrespective of the voltage supplied.

In scenarios where key equipment or a large number of electrical devices are voltage sensitive, a decision may be made to further evaluate the appropriateness and potential benefits of implementing voltage optimisation. Conversely, where key equipment or a large proportion of the equipment is non-sensitive a decision may be made not to proceed with further evaluation. See the example in the box.

Example of assessing voltage sensitivity

By using the voltage sensitivity checklist, a local council facilities manager undertook a high-level assessment to understand the site's voltage sensitivity. The assessment (using the template below) revealed that the site contained several voltage-sensitive types of electrical equipment. On the basis of this information, the facilities manager decided to proceed to Step 2 of this Guide (i.e. the evaluation stage).

Equipment	Voltage sensitivity		Identified at the site?	
	Sensitive*	Non-sensitive*	Yes	No
Lighting				
Fluorescent lamps (inductive ballast)	•		✔	
Refrigeration				
Refrigeration (uncontrolled)	•		✔	
HVAC				
HVAC (uncontrolled)	•		✔	
Industrial equipment				
Motors (loaded <25%)	•		✔	
Motors (uncontrolled)	•		✔	
Office				
Computers and laptops		•	✔	
UPSs		•	✔	

* See Toolkit 1 for further information on sensitive and non-sensitive equipment types.

Tip

If you are uncertain or are experiencing difficulties in understanding the appropriateness of voltage optimisation, engage a suitably qualified and experienced service provider (e.g. an electrical engineer or energy consultant) to provide support and guide you through the process.

Understanding your electricity consumption

To work out the potential savings from installing voltage optimisation, you need to understand your electricity consumption profile. Electricity invoices or metered data will support you to answer the following questions:

- How much electricity does your site consume (e.g. in kWh/year)?
- How much does your electricity cost (i.e. in AUD$/kWh and AUD$/kVA or AUD$/kW)?
- What is your site's demand profile (i.e. its maximum demand in kVA or kW)?
- What is your site load/energy balance (i.e. the percentages used by different systems such as lighting or HVAC)?

Understanding potential risks

Understanding the potential issues and risks associated with voltage optimisation is important for working out ways to minimise risk. Risks should be reassessed at every step of the process (i.e. throughout the evaluation (Step 2) and feasibility assessment (Step 3) to make sure that you minimise them. You can manage risks by using the process shown in Figure 4 and Table 3.

Figure 4: Initial risk management process as part of Step 1

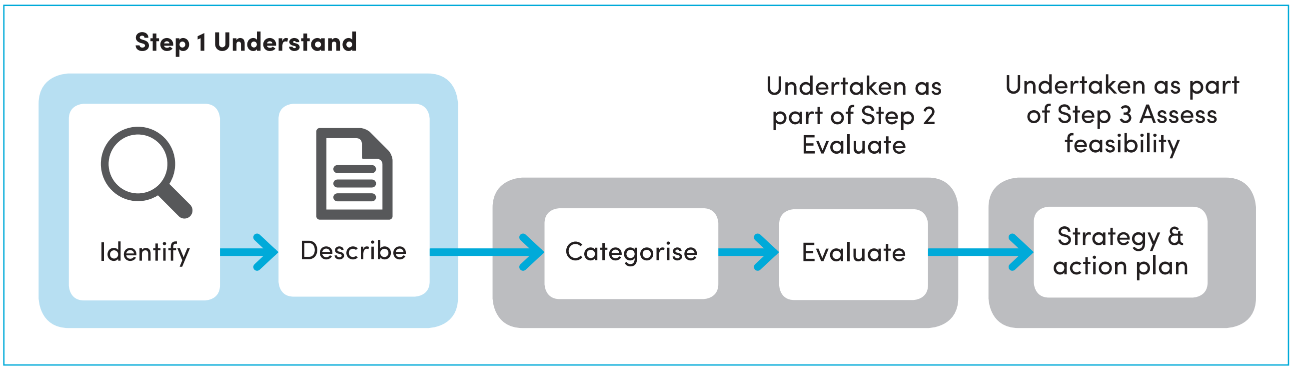


Table 3: How to manage the risks associated with voltage optimisation at your site

Process	Recommendation
Identify	Involve different stakeholders to identify the potential risks your site may experience directly or indirectly from the implementation of voltage optimisation. The identification process should: • involve key stakeholders who understand the site and the equipment • consider potential business scenarios (e.g. expansions or site plans) • involve stakeholders who understand voltage optimisation.
Describe	Develop a risk register that contains a description of each risk identified. The description should inform other stakeholders about the risk and the consequences if it occurs.

Tips

- Early identification of risks should minimise their impacts on costs and timing.
- Involve a variety of stakeholders in the risk identification process.
- See **Appendix 3** for the common issues and risks you should consider when assessing the suitability of voltage optimisation.
- See **Appendix 4** for examples of business scenarios. These will help you to decide whether to do a more detailed evaluation of voltage optimisation.

CASE STUDY: Step 1 Understand

Metcash considers voltage optimisation

Overview of the project

Metcash Ltd (Metcash), a wholesale distribution and marketing company specialising in grocery, fresh food, liquor, hardware and automotive parts and accessories, performed several energy audits of its sites to identify opportunities to save energy and operational costs. An opportunity was identified to implement voltage optimisation, with projected savings of up to 7% of a site's total electricity consumption.

Metcash found this opportunity compelling, as the technology was considered easy to install and the savings were substantial. Nonetheless, it was highlighted that the savings depended on the type equipment on site (i.e. the site's voltage sensitivity).

As Metcash has critical infrastructure on site (mainly freezer and refrigeration equipment), they decided to better understand their equipment and their loads before implementing the new technology. Additionally, they realised that to make an informed investment decision they needed to understand:

- the equipment history (e.g. the date when the freezer and refrigeration equipment were installed, and whether there had been any major retrofits)
- the medium- to long-term plans for the site's equipment (e.g. refrigeration system retrofitting plans, planned expansions, lease plans).

Activities undertaken

To understand the equipment and their equipment loads, Metcash:

- developed a detailed asset register (similar to the one in **Toolkit 2**)
- documented the history of the equipment (e.g. commissioning and major retrofits)
- considered the medium- to long-term plans for the sites
- engaged a consultant to examine supplier proposals regarding voltage optimisation.

Results

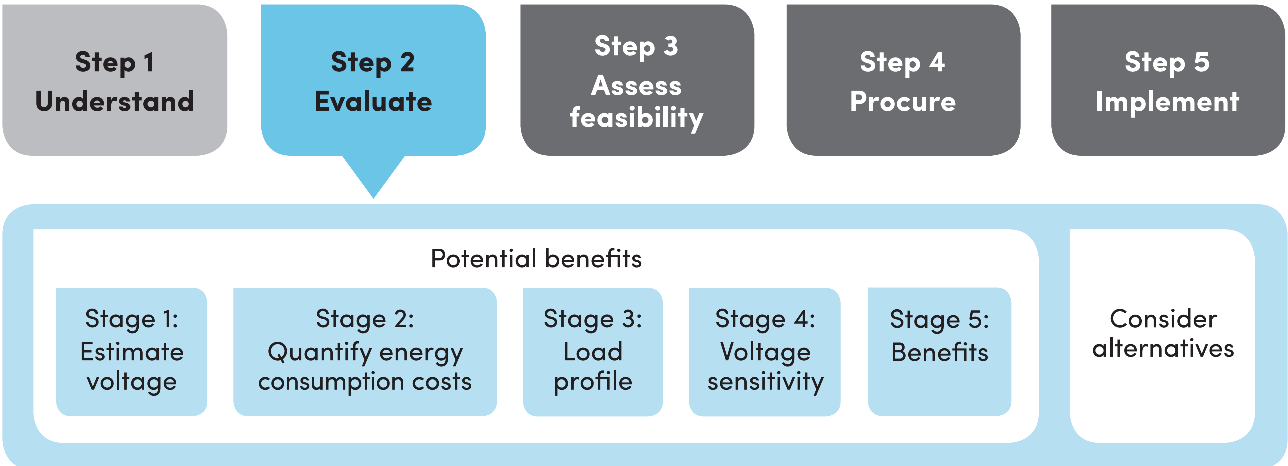
Key findings from these activities included the following:

- A number of sites used a mix of voltage-sensitive and voltage-non-sensitive equipment.
- Some of the sites were subject to major retrofit plans that included refrigeration system upgrades.
- There was a need to upgrade some sites' electricity meters to monitor real-time voltage and determine the need for voltage optimisation.

Key success factors

- ensuring a thorough understanding of the site and equipment
- developing an accurate and complete asset register
- considering the medium- to long-term plans for each site.

Step 2: Evaluate



Step 2 focuses on evaluating the potential benefits of voltage optimisation, as well as the alternative options and risks.

Tips

When evaluating voltage optimisation, it's important to include stakeholders who understand:

- your site's short, medium and long-term plans
- the electrical equipment installed at your site, its voltage rating, and its energy use as a proportion of total energy use
- your site's operations (e.g. hours of operation, equipment/process criticality, etc.).

Evaluating potential benefits

To evaluate the potential benefits of voltage optimisation, follow the tasks described below. An example of a retail store owner going through each of the tasks is provided to show how this is done in a practical way.

Task 1: Work out your voltage oversupply and voltage tolerances

The first task in evaluating the potential benefits of voltage optimisation is to determine the supply voltage levels and tolerances. This is important for assessing which voltage optimisation unit is appropriate for your site. To complete this task, you should have completed Step 1 and should have:

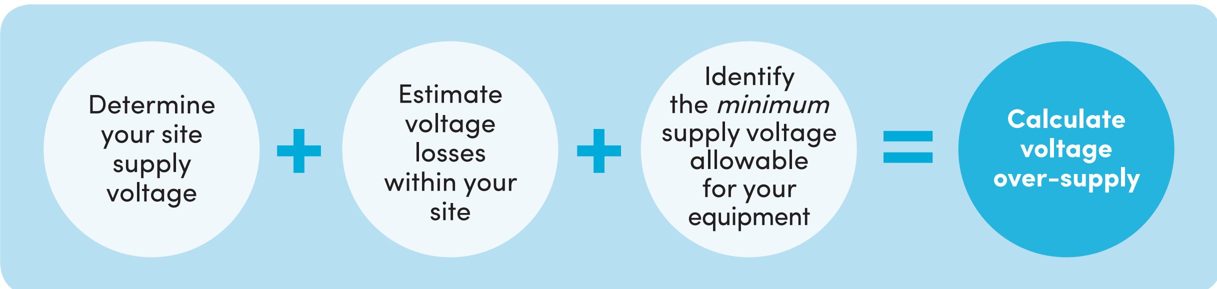
- an accurate and complete equipment register
- an electrical equipment load profile.

To determine the potential voltage oversupply to your site, you will need to:

- determine (or estimate) your site supply voltage
- estimate the voltage losses within your site
- identify the minimum supply voltage allowable for your equipment.

Tip

Remember that you are only estimating site voltage to develop an initial understanding as to whether your site may benefit from changes to voltage in the future. It is recommended to engage an electrical professional to accurately measure site voltage if you have completed all steps in the guide and are looking to continue your investigation.



Estimating your site's average supply voltage

You can determine your site's average supply voltage by estimating it, from information supplied by your electricity retailer, or you can use direct measurement. You should consider the pros and cons of each option, for example:

- Estimating the voltage supplied to the site might be inaccurate.
- Your electricity retailer may not be able to provide you with the information (only certain sites have the metering capabilities).
- Direct measurement is more accurate and can be done at various points in the electrical system, but it may require a long time and can be costly.

Estimating the voltage: Nominal voltage supply levels in NSW range between 216 V and 253 V. You can select a value within this range (e.g. 245 V) as an average supply voltage, or contact your electricity retailer for information.

Using voltage information supplied by your electricity retailer: For some sites, the electricity retailer may retrieve voltage information from each electricity meter installed on site. The electricity bill should give the National Meter Identifier (NMI) for each incoming meter installed at your site. The NMI is your site's unique meter identifier and will be required when you ask the retailer for electricity consumption information.

Tip

Ask your electricity retailer for details of the voltage supplied to your site.

Direct measurement: Direct measurement (e.g. using meters, a multimeter or a voltmeter) is the preferred method of measurement, as it will provide accurate data about your site's voltage supply levels. However, you need to remember the potential costs, the time taken, and the need to have electrical specialists do the measurements.

When performing direct measurement:

- Measure within the electrical circuit where the voltage is at its lowest point (i.e. the point of consumption farthest away from the supply).
- Performing direct measurement over an extended period of time (e.g. a month, week or season) to provide representative data. For example:
  - log over a typical operating cycle for the business (e.g. a shift, a day, a week, a month)
  - log over a period long enough to identify potential voltage dips due to load switching within the network.

If you need a higher degree of accuracy, more detailed measurement and monitoring can be done as part of Step 3 – Assess feasibility.

Tips

- Because of the dangers of direct measurement, all direct measurements must be done safely and be performed by a qualified electrical specialist.
- Some sites may meter voltage through a building management system (BMS) or equivalent, potentially reducing or eliminating the need for separate logging.

WORKING EXAMPLE: Estimating your site's average supply voltage

A retail store owner explored an opportunity to determine whether their site would benefit from voltage optimisation. As the evaluation was a preliminary exercise, the owner made an informed decision not to do direct measurement owing to time and resource limitations. Consequently, the owner estimated that the site was supplied electricity at 245 V.

The estimated voltage supply value was used throughout the evaluation process to estimate the benefits of voltage optimisation.

Estimating the average voltage losses within your site

Voltage within an electric circuit is subject to losses (i.e. voltage will drop as the electricity travels through an electric circuit). Australian Standard AS/NZS 3000 establishes a limit on the voltage drop within an electric circuit (up to 5% or 7% depending on the site; normally the voltage drop within an electric circuit is between ±1% to 2%). As part of the evaluation step and in line with the above-mentioned standards, a 5% voltage drop can be considered for evaluation purposes; it therefore represents the maximum allowable voltage drop within the circuit.

For a more accurate estimate of the losses, you can use the following methods to determine the voltage drop within an electric circuit:

- **Calculation:** Calculation methods can estimate losses on the basis of the distance and calibre of the wiring within the system.
- **Direct measurement:** Direct measurement can be done within an electric circuit at a point where the voltage is at its lowest (i.e. the point of consumption farthest away from the supply).

These calculations and measurements can also be done in ‘Step 3: Assess feasibility’.

WORKING EXAMPLE: Estimating the average voltage losses within your site

As a conservative measure, the site owner estimated a 5% voltage drop within the site’s electric circuit. The site will use this voltage drop when specifying the minimum allowable supply voltage for the site.

Estimating the minimum supply voltage allowable for your equipment

To estimate the minimum supply voltage required, the rated voltage levels for the electrical equipment should be assessed. Therefore, if you understand the minimum voltage levels of your equipment you can establish a voltage supply baseline. Note that voltage requirements vary among different types of electrical equipment. For example, sites may have ageing equipment that may have been designed for 240 V (rather than 230 V).

The minimum allowable supply voltage should also consider voltage losses (e.g. 5%) in the electrical system. For example, if 220 V has been determined as the minimum allowable voltage for certain equipment, the site should be supplied with ~232 V (i.e. 232 V – 5% = 220.4 V).

Tip

The rated voltage levels should have already been collated as part of ‘Step 1: Understand’ and recorded in your register.

WORKING EXAMPLE:
Identifying the minimum supply voltage allowable for your equipment

From the equipment information collected as part of 'Step 1: Understand', the site owner found that most of the electrical equipment was rated for 230 V and could operate at 220 V.

However, the refrigeration system was the original one from the 1990s and was planned for replacement later in the year. The refrigeration system had a rating of 240 V and consumed about 50% of the site's electricity usage. Therefore, the minimum allowable voltage was strongly influenced by the refrigeration system, leading to a required voltage level of 240 V.

Following the upgrade of the refrigeration system, the site's required voltage level was reduced to 230 V (because the new equipment was rated to 230 V).

As the new refrigeration system was able to operate at 220 V, the owner was able to consider reducing the voltage to 220 V.

Calculating the potential voltage oversupplied at your site

To estimate the potential overvoltage at your site, use these steps:

1. Add the potential voltage losses within the electrical circuit (e.g. 5%) to the minimum allowable voltage for the equipment (e.g. 220 V). This value represents the lowest potential voltage to be supplied to your site (i.e. 232 V).
2. Subtract the lowest potential voltage from the potential supply voltage level (e.g. 245 V – 232 V = 13 V).

WORKING EXAMPLE:
Calculating the potential voltage oversupply at your site

The site owner estimated that the site could be supplied with 232 V instead of 245 V. The owner used the following calculations:

Item	Estimate
Site supply voltage	245 V
Minimum voltage allowable for the site	220 V
Voltage losses within the site	5%
Potential reduced site supply voltage	232 V – 5% = 220 V
Summary	
Overvoltage supplied to site	245 V – 232 V = 13 V
Percentage overvoltage	13 V / 245 V x 100 =
Result	5.3%

Based on the simple calculation above, with a minimum voltage level of 220 V and 5% system losses, the mains voltage supply could be reduced to 232 V. This represents a reduction of 5.3%.

Task 2: Quantify energy consumption and costs

To quantify the energy consumption and costs, you will need to:

- determine the site's total electricity consumed
- determine energy costs
- consider the site's maximum demand.

To complete this task you will need invoices detailing electricity consumption (kWh) and cost per kWh over 12 months. These activities are described in detail below.

Determine the total electricity consumed by your site + Determine energy costs + Consider the maximum demand of your site = **Quantify energy consumption and costs**

Determining the total electricity consumed by your site

You can determine the total electricity consumed by your site (in kWh) by using the information you have obtained in 'Step 1: Understand'. Key considerations when doing this task include:

- the representativeness of the consumption profile
- any changes that may have influenced an increase/decrease in electricity consumption during any given period
- seasonal variations and how they affect your site.

> **Tips**
>
> - Consider at least 12 months' worth of electricity consumption data.
> - Highlight any increase or decrease in electricity consumption and the probable causes (e.g. weather influences (i.e. winter versus summer) or site operations that might have caused these fluctuations).

Interval data. 15- or 30-minute-interval electricity consumption data may be made available by electricity retailers for each electricity meter installed on site. You will need to give your NMI when you ask for electricity consumption information from the retailer.

> **Tip**
>
> Ask your electricity retailer for interval electricity-consumption data for your site.

Determine your energy costs

Electricity prices comprise a variety of charges (e.g. electricity charges, network charges, demand charges). Details of this information are given in your electricity invoice. Consider the total cost outlined in the electricity invoice in terms of total electricity consumed (i.e. AUD$/kWh). Make sure the billing period is aligned with the consumption period.

Considering the site's maximum demand

The maximum demand is the amount of energy required by your site at a given time and is measured in kilovolt amperes (kVA). Electricity suppliers charge users for the maximum electricity demand in a given period. Demand charges can be a material component of electricity costs and are based on historical maximum demand events (e.g. peaks) over a specified period.

Understanding the maximum demand helps you understand the required size of the voltage optimisation unit and can help in calculating potential demand charge savings.

Quantifying energy consumption and costs

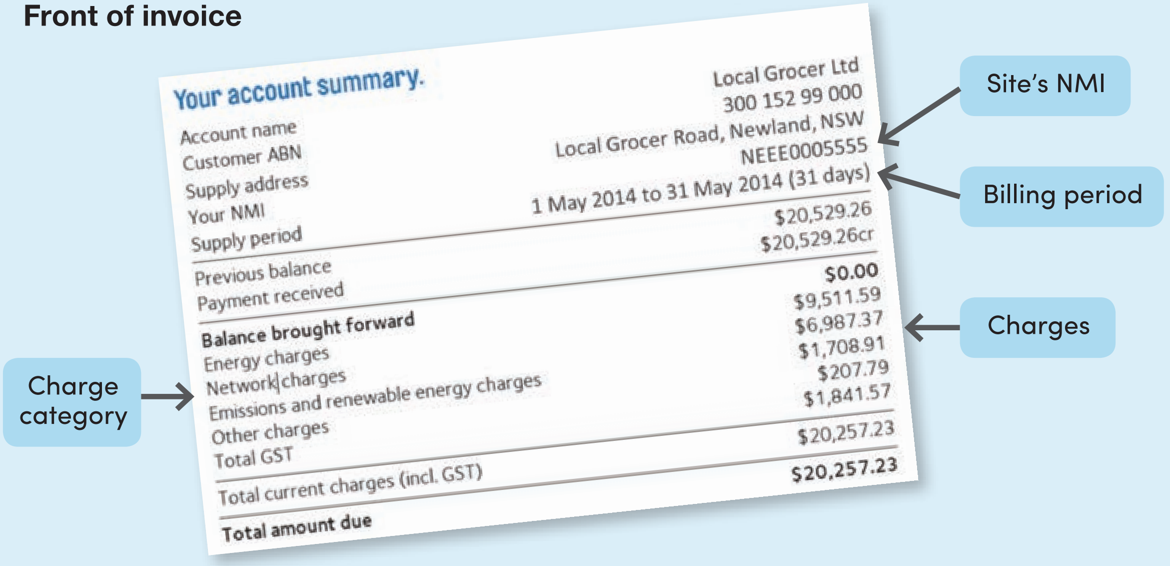
To quantify the energy consumption at your site, you will need to multiply the electricity consumed over a period of time by the energy cost for that period. You need to:

- consider a representative consumption period
- identify seasonal trends
- understand potential changes in your operations that may affect the energy consumed
- consider the different charges made by your electricity provider (e.g. electricity charges, network charges, demand charges)
- consider whether managing your maximum demand could be an opportunity for your site.

WORKING EXAMPLE: Quantifying energy consumption and costs

The site owner referred to a batch of recent electricity invoices. The image below highlights key components of the invoices.

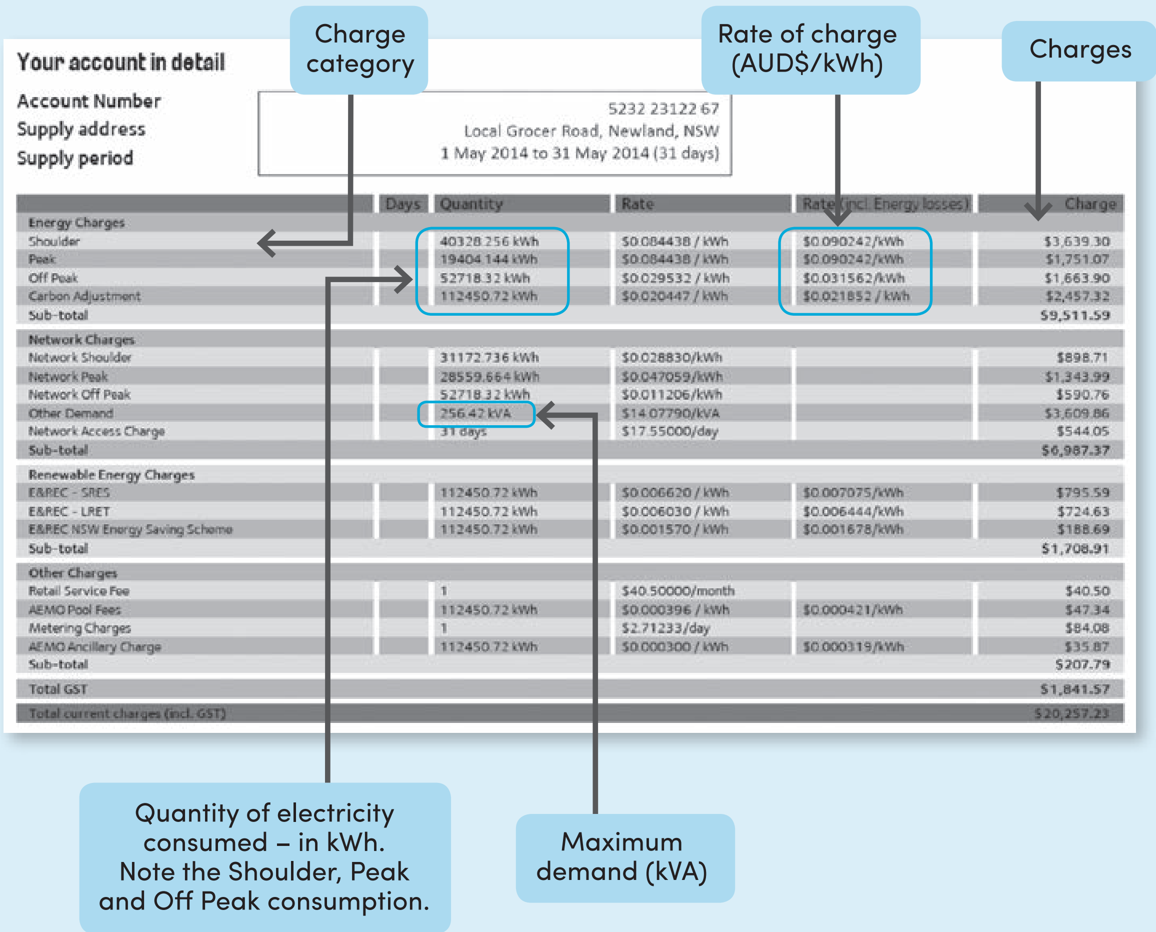
Front of invoice



Your account summary.

Account name	Local Grocer Ltd
Customer ABN	300 152 99 000
Supply address	Local Grocer Road, Newland, NSW
Your NMI	NEEE0005555
Supply period	1 May 2014 to 31 May 2014 (31 days)
Previous balance	$20,529.26
Payment received	$20,529.26cr
Balance brought forward	**$0.00**
Energy charges	$9,511.59
Network charges	$6,987.37
Emissions and renewable energy charges	$1,708.91
Other charges	$207.79
Total GST	$1,841.57
Total current charges (incl. GST)	$20,257.23
Total amount due	**$20,257.23**

Back of invoice



Your account in detail

Account Number	5232 23122 67
Supply address	Local Grocer Road, Newland, NSW
Supply period	1 May 2014 to 31 May 2014 (31 days)

	Days	Quantity	Rate	Rate (incl. Energy losses)	Charge
Energy Charges					
Shoulder		40328.256 kWh	$0.084438 / kWh	$0.090242/kWh	$3,639.30
Peak		19404.144 kWh	$0.084438 / kWh	$0.090242/kWh	$1,751.07
Off Peak		52718.32 kWh	$0.029532 / kWh	$0.031562/kWh	$1,663.90
Carbon Adjustment		112450.72 kWh	$0.020447 / kWh	$0.021852 / kWh	$2,457.32
Sub-total					$9,511.59
Network Charges					
Network Shoulder		31172.736 kWh	$0.028830/kWh		$898.71
Network Peak		28559.664 kWh	$0.047059/kWh		$1,343.99
Network Off Peak		52718.32 kWh	$0.011206/kWh		$590.76
Other Demand		256.42 kVA	$14.07790/kVA		$3,609.86
Network Access Charge		31 days	$17.55000/day		$544.05
Sub-total					$6,987.37
Renewable Energy Charges					
E&REC - SRES		112450.72 kWh	$0.006620 / kWh	$0.007075/kWh	$795.59
E&REC - LRET		112450.72 kWh	$0.006030 / kWh	$0.006444/kWh	$724.63
E&REC NSW Energy Saving Scheme		112450.72 kWh	$0.001570 / kWh	$0.001678/kWh	$188.69
Sub-total					$1,708.91
Other Charges					
Retail Service Fee		1	$40.50000/month		$40.50
AEMO Pool Fees		112450.72 kWh	$0.000396 / kWh	$0.000421/kWh	$47.34
Metering Charges		1	$2.71233/day		$84.08
AEMO Ancillary Charge		112450.72 kWh	$0.000300 / kWh	$0.000319/kWh	$35.87
Sub-total					$207.79
Total GST					$1,841.57
Total current charges (incl. GST)					$20,257.23

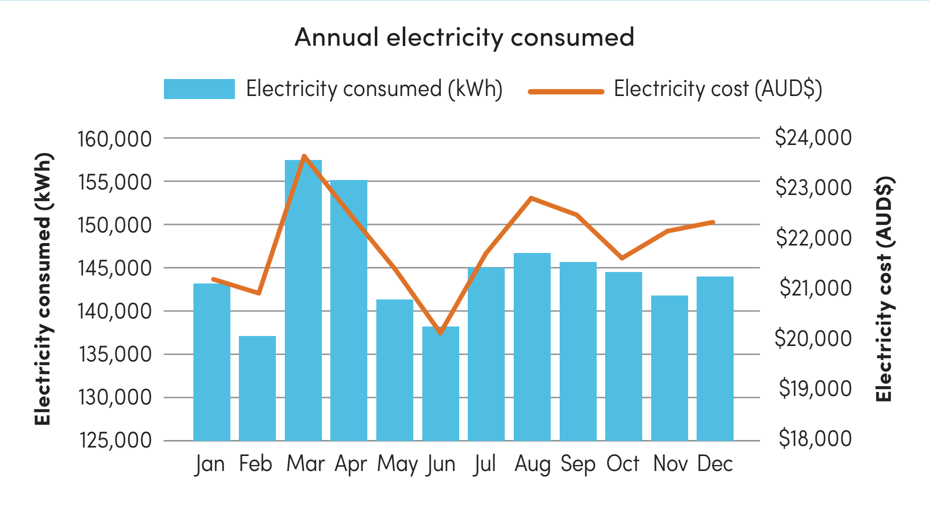
The site owner created the following table by using the invoices for a year. With this, the owner was able to quantify the annual energy consumed and the cost to the site.

Month	Electricity consumed (kWh)	Electricity cost (AUD$)	Electricity price (AUD$/kWh)
January	143,172	$21,155.76	$0.1478
February	137,091	$20,918.81	$0.1526
March	157,451	$23,692.77	$0.1505
April	155,121	$22,532.63	$0.1453
May	141,312	$21,408.37	$0.1515
June	138,185	$20,112.92	$0.1456
July	145,021	$21,720.77	$0.1498
August	146,688	$22,842.74	$0.1557
September	145,630	$22,504.36	$0.1545
October	144,497	$21,626.75	$0.1497
November	141,802	$22,175.33	$0.1564
December	143,972	$22,355.56	$0.1553
Total	**1,739,941**	**$263,046.78**	**$0.1512***

* Average price

The site owner was able to plot the electricity consumption and the cost throughout the year. Through this exercise, the site owner was able to identify the following observations:

- Higher electricity consumption occurred in March and April (see graph below). The owner was able to associate this increase in electricity consumption to works performed by a contractor on site.
- The owner also noted that for the rest of the year (i.e. July to December) the site's electricity consumption was relatively constant.



Task 3: Determine the load profile

To complete this task you should:

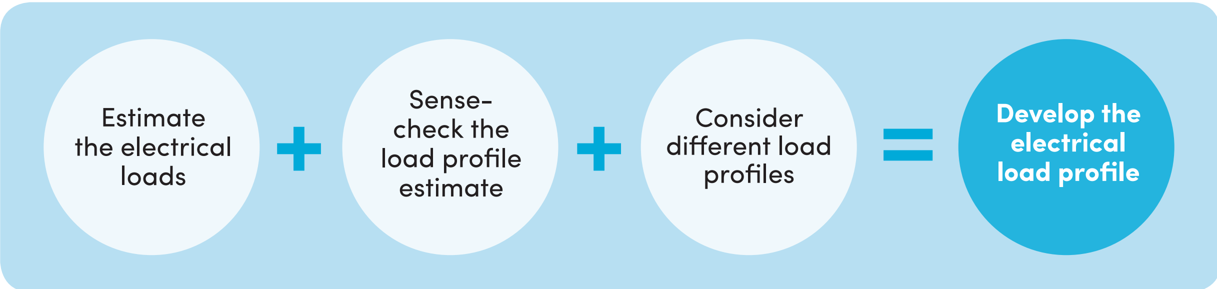
- understand your site's electricity consumption and cost profile
- make sure your electrical equipment register is complete and accurate.

By completing this task you will develop an electrical load profile that will help you to identify key equipment or areas that may benefit from voltage optimisation.

To develop the electrical load profile, you will need to:

- estimate the electrical loads of key equipment
- sense-check the load profile estimate
- consider different load profiles.

These activities are described in detail below.



Estimating the electrical loads of key equipment

The key steps to estimating electrical loads are:

- Gathering equipment information. This information should be documented as part of your development of an equipment register (as described in 'Understanding your electrical equipment').
  - List power ratings (kW) for each type of electrical equipment.
  - List the number of units of each type of equipment.
- Assessing equipment characteristics
  - Calculate maximum load (kW) by multiplying the power rating by the number of units of each type of equipment.
  - Determine the equipment utilisation factors (%), namely the percentage of time for which the electrical equipment is operating during the period of time evaluated.
- Estimating the load profile
  - Determine the operating hours over a period of time (e.g. hours/month).
  - Determine the electricity consumed (kW) over a period of time (e.g. kWh/month).
  - Determine the percentage breakdown of electricity consumption by equipment type (e.g. air-conditioning uses 30% of the total electricity consumption, lighting uses 35%, etc.)

Sense-checking the load profile estimate

Compare the estimated electricity consumed (in kWh) and the invoiced electricity consumed (in kWh). This will help you to assess the accuracy and completeness of your estimates.

To do this comparison, you need to:

- compare the total electricity consumption (in kWh) against the invoice (make sure they are for the same period of time)
- consider whether there may be additional equipment that you might not have evaluated as part of the assessment (e.g. emergency lighting); allow for some contingency in your calculations
- vary either the utilisation factor or the operating hours if the estimated electricity consumed and the invoiced electricity consumed aren't the same
- sense-check the percentage breakdown of electricity consumption by equipment type.

Consider asking an energy management specialist to help you complete this step.

Considering different load profiles in different scenarios

Load profiles can vary depending on a site's operations and how the equipment is used. Different load profiles can be estimated for different scenarios, thus increasing the assessment accuracy. Therefore, depending on how the equipment is used, electrical load profiles may need to be produced for different operating periods, such as:

- days versus nights
- full production versus reduced production versus idle time
- weekdays versus weekends
- winter versus summer.

Developing an electrical load profile for your site

Using your asset register and the key electrical equipment information, you should now be in a position to develop an electrical load profile.

Refer to the working example in the box. An electrical load profile template can be found in **Toolkit 3**.

WORKING EXAMPLE: Developing an electrical load profile for your site

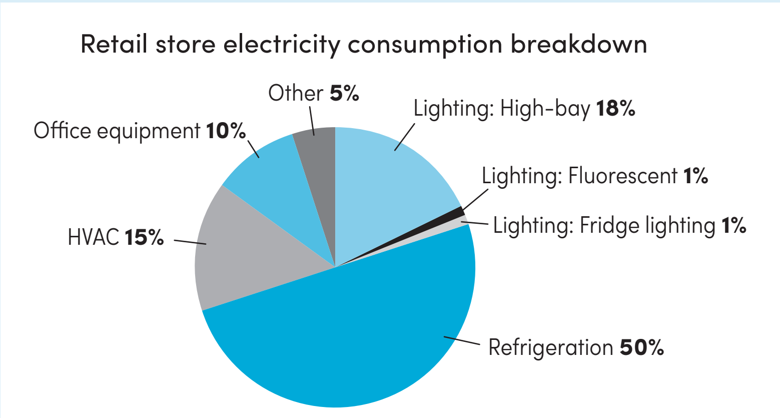
A retail store owner has developed a table of the rated power (in kW) of key electrical equipment along with the number of units to estimate the load profile of the site. The site owner made informed assumptions about electrical equipment utilisation factors (i.e. the percentage of time for which the electrical equipment is operating during the period of time evaluated) on the basis of their knowledge of the site.

For the purposes of this assessment, the retail store owner considered a monthly period for estimating the electrical load of the site. Referencing previous electricity bills, the store owner knows that the kWh consumption of the site is between 140,000 and 165,000 kWh a month.

Type	Power rating (kW)	Number of units	Maximum load (kW)	Utilisation factor (%)	Hours/ month	kWh/ month	Break-down (%)	Cost (AUD)[1]
Lighting: High-bay	0.6	120	72	100%	365	26,280	18%	$3,973.54
Lighting: Fluorescent	0.1	100	10	50%	365	1825	1%	$275.94
Lighting: Fridge lighting	0.1	50	5	50%	730	1825	1%	$275.94
Refrigeration	100	1	100	100%	730	73,000	50%	$11,037.60
HVAC	30	2	60	50%	730	21,900	15%	$3311.28
Office equipment	1	40	40	100%	365	14,600	10%	$2207.52
Other	5	4	20	100%	365	7300	5%	$1103.76
Total	–	–	**307 kW**	–	–	**146,730**	**100%**	**$22,185.58**

1 Assuming an electricity cost of $0.1512 AUD/kWh

On the basis of the load estimate, the owner worked out that the site's electrical profile could be broken down into the following:



Through this process the site owner found that the refrigeration system consumed the most electricity.

Task 4: Determine the voltage sensitivity of the equipment

To complete this task you should have an electrical load profile for your site. Next, you need to evaluate the equipment voltage sensitivity. This will be a key input to understanding any potential savings from using voltage optimisation.

Voltage sensitivity assessment

Determine the voltage sensitivity of the main electricity-consuming equipment installed on site. See Table 5 for the sensitivities of the most common equipment types. See the box for a working example.

WORKING EXAMPLE: Determining voltage sensitivity

The retail store owner developed a table to record the voltage sensitivity of the equipment on site.

			Voltage sensitivity	
Type	**kWh/month**	**Breakdown (%)**	**Sensitive**	**Non-sensitive**
Lighting: high-bay	26,280	18%	•	
Lighting: fluorescent	1825	1%		•
Lighting: fridge lighting	1825	1%		•
Refrigeration (uncontrolled)	73,000	50%	•	
HVAC (uncontrolled)	21,900	15%	•	
Office equipment	14,600	10%		•
Other	7300	5%		•
Total	**146,730**	**100%**		

Task 5: Assess potential benefits

This last task of the evaluation step is to calculate the potential benefits of implementing voltage optimisation. You can then evaluate the potential benefits against the costs associated with a) further evaluating the technology and b) implementing the technology.

To calculate the potential benefits, you should understand the relationship between how a variation in voltage affects the power consumed by electrical equipment. As you can see from the following equation, any voltage variance will have a twofold impact on the power consumed (e.g. if the voltage varies by 1% the variation in power would be 2%).

$$\text{Power (W)} = \frac{\text{Voltage (V)}^2}{\text{Resistance }(\Omega)}$$

If a site is supplied at 245 V and the intention is to reduce that to 235 V, the reduction will be 10 V, namely -4.08%. This reduction will be experienced only by the voltage-sensitive electrical equipment. Consequently, the potential reduction in electricity consumption can be obtained through:

- the decrease in electricity consumption by voltage-sensitive equipment
- the potential voltage reduction (e.g. -4.08%); and
- the twofold impact of the change in voltage on the power consumed (i.e. multiplication factor = 2).

The working example in the box shows you how you can determine the potential savings.

WORKING EXAMPLE: Assessing potential benefits

In this example, the site would have a reduction of 11,080 kWh a month. This represents energy savings of about AUD$1,675. To work this out, the owner performed several calculations.
A sample calculation considering high-bay lighting is as follows:

26,280 kWh x 4.08% = 1,072 kWh x 2 = 2,144 kWh

Type	kWh/ month	Breakdown (%)	Voltage sensitivity		Potential savings	
			Sensitive	Non-sensitive	kWh/month	Cost (AUD)[1]
Lighting: high-bay (magnetic ballast)	26,280	18%	•		2144	$324.24
Lighting: fluorescent (inductive ballast)	1825	1%		•	–	–
Lighting: fridge lighting	1825	1%		•	–	–
Refrigeration (uncontrolled)	73,000	50%	•		5957	$ 900.67
HVAC (uncontrolled)	21,900	15%	•		1787	$ 270.20
Office equipment	14,600	10%		•	1191	$ 180.13
Other	7300	5%		•	–	–
Total monthly	**146,730**	**100%**			**11,080**	**$1675.24**

1 Assuming an electricity cost of $0.1512 AUD/kWh

Evaluate alternative options

When you evaluate an investment option, alternatives should be considered to test and evaluate the benefits and risks associated with the option. An investment in energy efficiency is no different. Alternative options should be considered on the basis of the specific circumstances of your site. You should also consider planned and potential changes to your site's operations (e.g. modifications, replacements, upgrades) and seasonal impacts.

To evaluate different options you need to work out the potential energy savings, financial costs and benefits (e.g. by working out a simple payback period). For example, alternative energy-saving options at a site may include lighting systems upgrades, upgrade HVAC equipment, or installing variable speed drives (VSDs) on motors.

Tips

- Voltage optimisation should be considered against planned or potential changes to your site (e.g. modifications, replacements, upgrades) and other energy management alternatives.
- If you use an independent energy-savings professional to assess your voltage optimisation, ask them to consider other energy-saving opportunities in their assessment.

Assess risks

After the initial risk management process (see Step 1), you should categorise and evaluate the risks you previously identified. This should include the steps in Figure 5 and Table 4.

Figure 5: Risk management process in Step 2

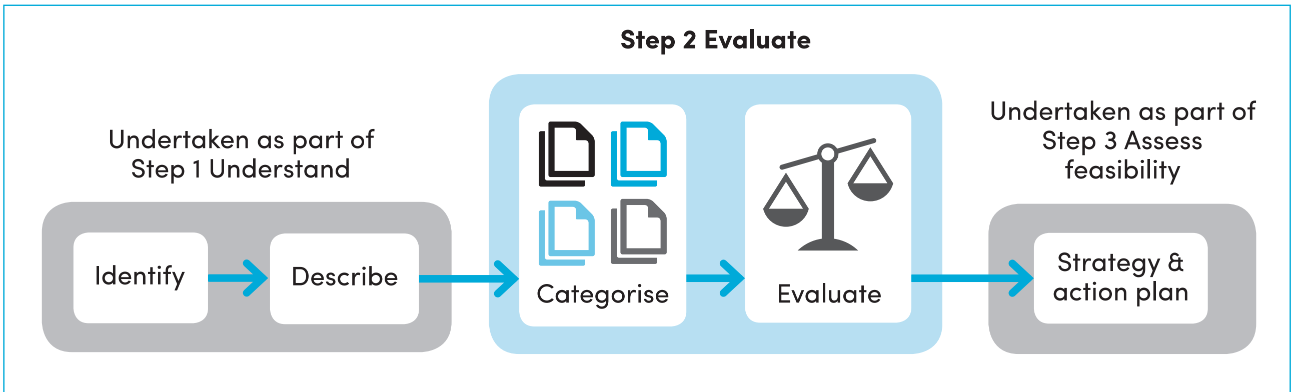


Table 4: Risk management details in Step 2

Process	Recommendation
Categorise	Categorise risks to understand the relationship between them (e.g. safety, regulatory, financial, electrical infrastructure, supply).
Evaluate	Evaluate risks and prioritise them on the basis of their criticality. Criticality can be determined on the basis of the likelihood of the risk occurring and the consequences if it does occur.

Tips

- See **Appendix 3** for common issues and risks to consider when assessing the suitability of voltage optimisation.
- See **Appendix 4** for examples of business scenarios to support your decision on whether to do a more detailed evaluation of voltage optimisation.

CASE STUDY: Step 2 Evaluate

News Corp Corporate Head Office evaluates the appropriateness of voltage optimisation

Overview of the project

News Corp Australia (News Corp), a global company operating in diversified media, news, education, and information services, considered the appropriateness of voltage optimisation at its Corporate Head Office, located in Surry Hills, NSW.

The office was formerly used for industrial purposes. Electricity is supplied to the site and is consumed for HVAC purposes, lighting and office equipment (e.g. computers). Site managers have done a number of energy efficiency initiatives (such as lighting system improvements) and are planning a HVAC chiller upgrade.

Activities

The company engaged a consultant to help evaluate of the suitability of voltage optimisation for the site. The evaluation focused on the following questions:

- How sensitive is our equipment to voltage?
- What things are we planning to do that might affect our electricity consumption?
- What are the potential energy savings and cost benefits associated with implementing voltage optimisation for the site?
- Should we proceed or not proceed with voltage optimisation?

On the basis of the company's clear understanding of the site's electricity-consuming equipment, assets and electricity-consumption profile, it was found that voltage optimisation would have the greatest benefit for the HVAC system.

Outcomes

Because of a scheduled chiller upgrade, News Corp made an informed decision to postpone judgment on the appropriateness of voltage optimisation.

News Corp developed a greater understanding of the electricity consumption characteristics of the site and the significance of considering current or future activities that might influence the effectiveness of voltage optimisation.

Step 3: Assess feasibility

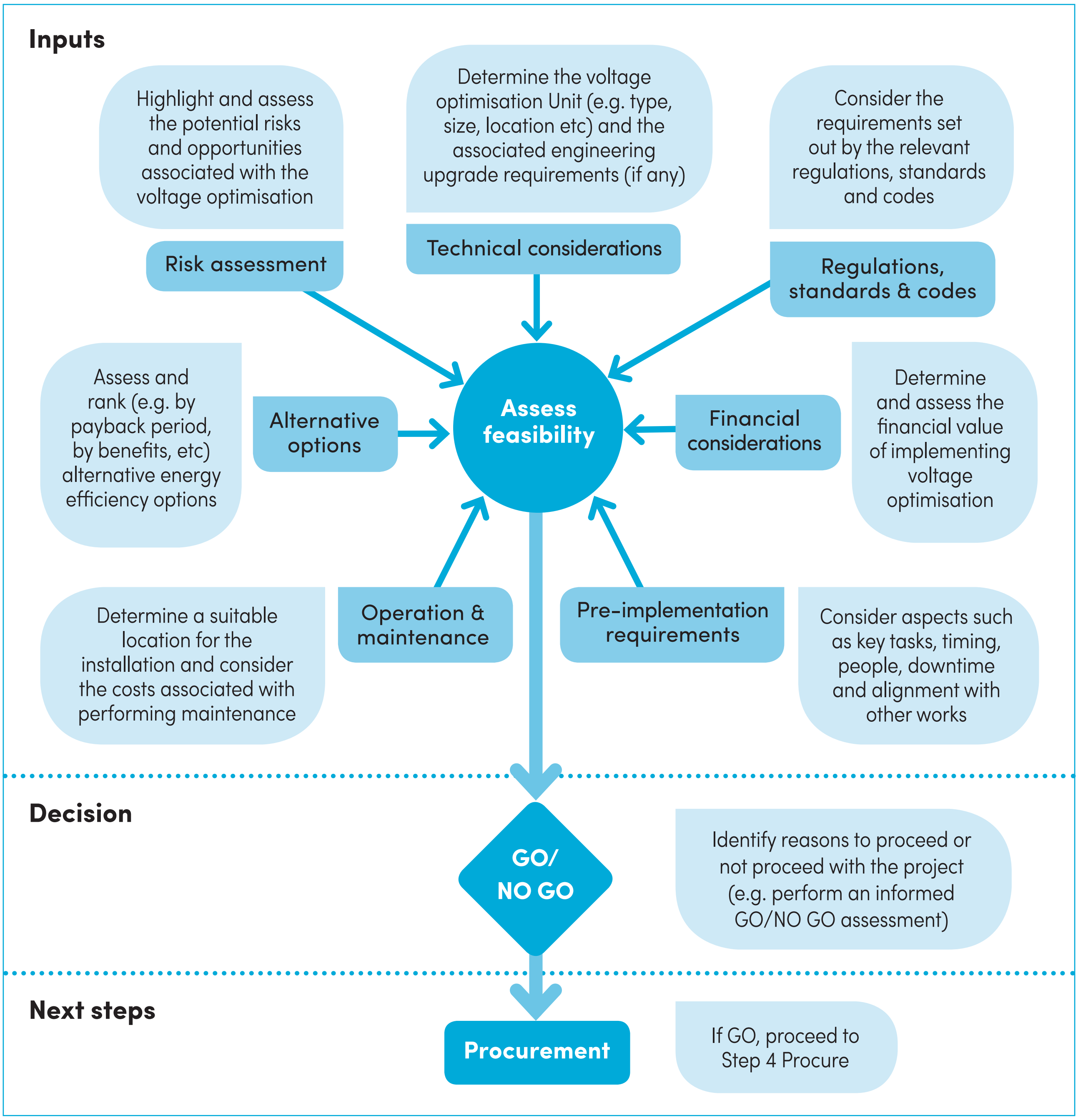
Step 1 Understand | **Step 2** Evaluate | **Step 3** Assess feasibility | **Step 4** Procure | **Step 5** Implement

This step focuses on performing a feasibility assessment of voltage optimisation. The feasibility assessment will highlight in greater detail the potential pros and cons of voltage optimisation at your site. By using the following key considerations, you should be able to make a decision about whether to procure and implement voltage optimisation. The key considerations in Figure 6 are explored in further detail as part of this step.

Tip

Depending on the complexity of your site, it's usually best to engage a specialist to do a feasibility assessment to work out the suitability of voltage optimisation.

Figure 6: Key considerations in working out the feasibility of voltage optimisation



Inputs

Financial considerations

You should assess a number of financial considerations of implementing voltage optimisation. Importantly, you should consider the total cost of owning the technology. The total cost of ownership considers all costs in addition to the up-front capital costs. The key considerations in Table 5 should help you to work out the additional costs and financial factors required to make an informed decision.

Table 5: Key financial considerations in working out the feasibility of voltage optimisation

Category	Key considerations
Budget constraints/ limitations/targets	• internal costs • activities and resources • performance metrics/hurdles
Costs	• up-front capital • operating and maintenance costs • contingency costs • specialists • engineering support
Internal financial considerations	• simple payback periods • internal rate of return • total cost of ownership
Others	• built-in contingency (based on an appropriate percentage of the items above) • consideration should also be given to alternative funding streams (e.g. Energy Saving Certificate (ESC) generation)

Tips

The total cost of ownership (TCO) can be used to consider the potential direct and indirect costs associated with voltage optimisation.

TCO = Capital costs + operational costs + ongoing costs

Capital costs:

- purchase of a voltage optimisation unit
- engineering works (e.g. civil, structural, electrical).

Operational costs:

- procurement costs
- commercial costs (e.g. warranty, guarantee)
- labour costs (e.g. installation, testing)
- certification requirements.

Ongoing costs:

- inspection costs (e.g. inspections over the life of the asset)
- maintenance costs (e.g. regular maintenance costs over the life of asset).

Other potential cost considerations:

- shutdown/downtime required for installation and commissioning of the voltage optimisation unit
- monitoring and verification
- spares cost (including availability of parts)
- training and accreditation requirements
- decommissioning costs.

Tips

- Consider the total cost of implementing voltage optimisation at your site. The total cost should consider all potential costs on top of the capital costs of the technology.
- Consider a financial scenario that estimates the cost of not implementing voltage optimisation.

Financing options

There are a variety of energy efficiency and renewable energy financing options available to NSW businesses, including grants and funding mechanisms. These options generally fall into three categories: bank loans, lease agreements and other agreements with local municipalities and suppliers. **Appendix 5** gives an overview of these financing categories.

Tip

For more details on how to choose the most suitable financing option for your site, see the Energy Efficiency and Renewables Finance Guide (2014) produced by OEH.

Funding options

Funding options are also available to NSW businesses to encourage energy efficiency. The Energy Savings Scheme (ESS) is available to certain businesses implementing voltage optimisation or upgrading voltage-sensitive equipment. A summary of the ESS is outlined in **Appendix 5**.

Tip

For comprehensive details of the ESS see www.ess.nsw.gov.au.

Regulations, standards and codes

Under NSW legislation, there are substantial penalties for failing to carry out electrical installation work in accordance with regulations and technical standards. These technical standards are the Australia/New Zealand wiring rules and the NSW Service and Installation Rules.

Additionally, because of the level of risk associated with modifying and installing electrical equipment, adherence to relevant regulations, standards and codes is critical. You should get appropriately qualified personnel to do assessments and works associated with voltage optimisation.

Tip

For more information about the technical standards and the rules, see the NSW Department of Fair Trading's website at www.fairtrading.nsw.gov.au.

Technical considerations

Finding a suitable location to install a voltage optimisation unit depends on a number of considerations, including:

- the type of voltage optimisation unit
- specific engineering requirements.

Table 6: Technical considerations for installing a voltage optimisation unit

Technical category	Key considerations
Voltage optimisation unit type	• type: consider the selection of the type of unit required (e.g. fixed voltage regulator, dynamic voltage regulator) • size: consider the size (e.g. kVA rating) of the voltage optimisation unit. The size will depend on the unit's purpose and type • compatibility of the unit with other equipment on site (e.g. Building Management System, IT equipment, production equipment)
Civil and structural	• the application and location of the voltage optimisation unit (e.g. Will the unit service the whole site, or is it equipment/area specific?) • the size of the voltage optimisation unit • the availability of space for the voltage optimisation unit, and the allowance of adequate ventilation • the condition of the structure (e.g. the unit will need to be installed on material with sufficient structural strength). Depending on the size and weight of the unit, consider the load capacity of the structure
Electrical	• the availability and condition of cable routes (e.g. review drawings, single line diagrams) • accessibility of the area for maintenance or inspections to be performed

Operations and maintenance

You should consider the operation and maintenance requirements of a voltage optimisation unit. These requirements include, but are not limited to, the key considerations in Table 7.

Table 7: Operation and maintenance considerations for installing a voltage optimisation unit

Operations and maintenance category	Key considerations
Operations	• system redundancy (e.g. consider adding a bypass switch in case the unit fails) • authorised and qualified personnel to operate/install the voltage optimisation unit • user interface to control the voltage optimisation unit • suitable timing to install the voltage optimisation unit • operational impacts if failure occurs
Maintenance	Although direct maintenance requirements are typically low for a voltage optimisation unit, consider the following: • perform periodic inspections (e.g. external checks, internal checks, taking liquid samples, and performance checks) • perform an annual thermal scan of the electricity supply infrastructure (including the voltage optimisation unit) • make sure maintenance is performed by qualified and experienced personnel • planning and scheduling maintenance activities.
Environment	In the event a transformer needs to be replaced, consider the implications of disposing of the existing unit (e.g. accountability, environmental stewardship, costs).

Alternative options

Alternative options were evaluated in 'Step 2: Evaluate'. Nonetheless, at this point you should reassess the viability, advantages and disadvantages of voltage optimisation against alternative options. You can do this by building a matrix that considers the different options against comparative metrics such as energy savings or payback period. **Toolkit 5** provides an example of a decision matrix analysis template.

Tip

Document the different alternative options considered and the reasons for not using of each option.

WORKING EXAMPLE: Alternative options

A facilities manager is considering a number of initiatives to reduce the energy consumption and costs associated with operating a large warehouse. the facilities manager has identified lighting upgrades and voltage optimisation as key opportunities for the site.

The warehouse building uses mainly magnetically controlled lighting, which is considered voltage sensitive. The facilities manager is considering upgrading the lighting system to a more efficient, voltage-non-sensitive, technology such as LEDs.

As part of evaluating the potential benefits of voltage optimisation, the facilities manager has considered different scenarios for the warehouse, including the lighting system upgrade. At this point, the FM undertook a process to rank the alternative energy efficiency options. In this case voltage optimisation was not selected as a top ranked alternative for the site and the facilities manager went ahead with an energy efficient lighting upgrade.

Similar situations could occur if the facilities manager were to intend to:

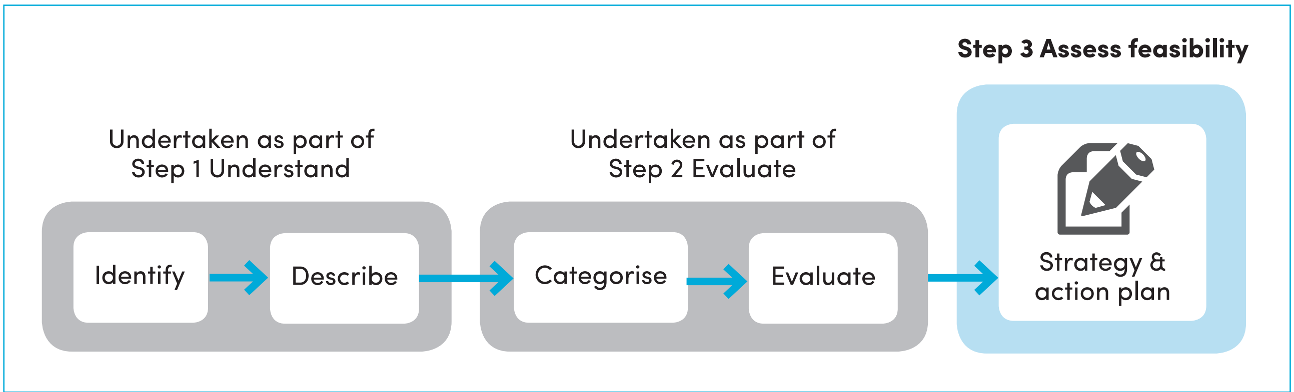
- upgrade motors/fans to include control devices (e.g. installation of VSDs)
- replace existing voltage-dependent equipment with voltage-non-sensitive equipment
- modify the site's operations (e.g. increase/decrease production, change operating hours).

Risk management

A key feature of a detailed feasibility assessment is the development of strategies to mitigate potential risks. You should prioritise and develop strategies and action plans to reduce the likelihood and consequence of the risks.

Following the risk management process introduced in Step 1 and evaluated in Step 2, you should perform a strategy and action plan to mitigate the risks previously identified (Figure 7).

Figure 7: Risk management process in Step 3



WORKING EXAMPLE: Risk management

A retail store owner has decided to implement voltage optimisation. Because of the criticality of electricity supply to the business, the store owner performed a high-level risk assessment.

The key risk identified by the owner was the importance of ensuring the operability of the refrigeration system. The refrigerated area contains products such as meat, dairy foods and other perishables that could easily spoil. The owner has recognised that any issues in this area may result in operational and financial risks to the business that need to be mitigated.

For this risk, the store owner undertook the following process:

- defined the risk and the potential consequences
- prioritised the risk on the basis of its likelihood (e.g. low) and consequence (e.g. high)
- developed an action plan to mitigate the risk.

Technical category		**Risk analysis (prioritisation)**			**Action plan**
Identified risk/ hazard	**Leading to…**	**Likelihood**	**Consequence**	**Risk rating**	**Mitigation measure (example only)**
Lack of refrigeration system operability	• Site shutdown/ blackout • Damage to refrigerated stock • Loss of revenue	Low	High	High	Install a bypass switch Have emergency back-up power

Pre-implementation requirements

You should develop a work program that considers such factors as key tasks, project scheduling and alignment to other works. You could also develop a work breakdown structure (or equivalent) that considers:

- equipment lead times and spares
- civil and electrical work requirements
- the sequence and duration of installation activities
- estimated project constraints
- metering and verification considerations.

Decision

At the end of this step you should be able to make the decision as whether to go ahead with considering voltage optimisation for your site, or not. A go/no go assessment considers all the pros and cons of implementing voltage optimisation at your site. You should do a go/no-go assessment to work out whether to proceed to the procurement step.

You should involve key stakeholders in the go/no-go assessment.

Next steps

If the decision is to:

- proceed with the voltage optimisation implementation then you need to allocate the recommended relevant resources (i.e. financial and people) to the procurement step (see 'Step 4: Procure')
- not proceed with the voltage optimisation implementation then you need to document the reasons for this decision and communicate them relevant stakeholders.

Tip

You may need to develop a business case to support internal decision-making processes. OEH provides training to businesses that need help with developing business case proposals for energy efficiency projects. A template can be found in **Toolkit 4**. For more information, see: www.environment.nsw.gov.au/business/business-case-training.htm.

CASE STUDY – Step 3: Assess feasibility

A regional NSW RSL Club achieves cost reductions by installing voltage optimisation

Overview of the project

The manager of a regional RSL club attended a voltage optimisation seminar. The seminar was facilitated by a colleague who had recently installed a voltage optimisation unit. The seminar was based on the success of voltage optimisation and encouraged other RSLs to consider the technology.

Activities

On the basis of the information obtained at the seminar, the RSL manager undertook a high-level due diligence exercise. The exercise included facilitating interviews with other RSL clubs to understand:

- how voltage optimisation technology works
- their experience with voltage optimisation technology.

The Manager received positive responses from the interviews (i.e. the interviewed RSL clubs representatives claimed that they would implement voltage optimisation once again). As a result, the manager initiated a thorough feasibility assessment to:

- consider the appropriateness of voltage optimisation at the site
- evaluate the potential savings from implementing voltage optimisation
- manage the risk of blackouts, which are a major risk to the business.

The feasibility assessment identified the following:

- The site had a large number of voltage-sensitive equipment items. This equipment was being affected by voltage variations (i.e. the equipment was being damaged and required regular replacement).
- The site would benefit from installation of a dynamic voltage optimisation unit.

The RSL club subsequently engaged a voltage optimisation supplier to procure and install a voltage optimisation unit on site.

Additional activities on site

Within a month of the installation of the voltage optimisation unit, the RSL installed a solar photovoltaic system. As a result, the identification of benefits solely attributable to the voltage optimisation unit was unclear.

Outcomes

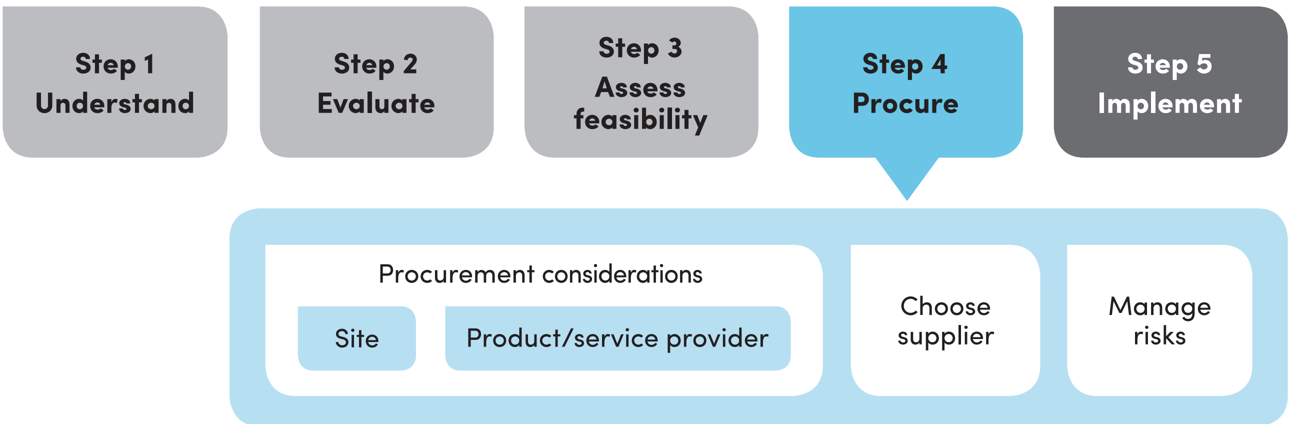
Since the installation of the voltage optimisation unit and the solar photovoltaic system, the site has experienced:

- an overall reduction in electricity purchased from the grid, generating savings to the site
- an estimated reduction in maintenance costs, mainly as a result of the decrease in damage to voltage-sensitive equipment due to voltage fluctuations (e.g. television screens and security system components)
- an improved power factor.

Key success factors

- understanding, evaluating and assessing the electrical equipment on site
- identifying the potential benefits and risks associated with voltage optimisation unique to the site
- performing a thorough feasibility assessment of the technology and its suitability for the site.

Step 4: Procure



After Steps 1 to 3 are complete, Step 4 aims to guide you through several of the elements needed to procure a voltage optimisation unit. This Step provides general guidance; it should always follow your company's internal procurement procedures. This Step considers:

- site considerations: things related to the site that you need to tell the product or service providers about
- product and service provider considerations: things that you should ask, or expect from, product or service providers
- considerations when choosing a supplier: things to think about when choosing a supplier.

You should continuously manage any risks by revisiting your risk register and applying the mitigation strategies defined there.

Site considerations

You should consider the site procurement considerations in Table 8 when you are doing your paperwork to procure a voltage optimisation unit (e.g. tendering documents or specifications). Product and service providers typically need the information below to be able to supply an accurate proposal. Preparing it will also make sure that you define the project's requirements and expectations.

Table 8: Site considerations for procurement

Focus area	Key considerations
Scope of works	• outline the intended scope of works for the supplier to follow • add inclusions and exclusions • outline the objectives intended to be reached as a result of the implementation of voltage optimisation
Electricity consumption	• provide an overview of the equipment on site and its use (e.g. hours of operation) • if available, add the model, make and minimum recommended voltage of key electrical equipment • add sub-metered information (if available) • add your site's supply voltage level (if available)
Financials	• provide information related to your site's electrical expenditure (e.g. electricity invoice) • include financial expectations (if applicable)
Commercials	• provide information on preferred warranties, including inclusions and exclusions

Product and service provider considerations

When you are doing your paperwork to procure a voltage optimisation unit (e.g. when tendering documents or specifications), think about what information to ask for from the product or service providers. Key considerations include those in Table 9.

Table 9: Product and service provider considerations for procurement

Focus area	Key considerations
Electricity consumption	Ask for clear and transparent calculations of potential energy savings and benefits.
Financials	Ask for clear and transparent calculations of financial benefits.
Commercials	Ask for information on: • warranties available, including inclusions and exclusions • defect periods and duration of claims covered by warranties • energy savings and performance guarantees (if any) • treatment of consequential losses • expected life of equipment.
Compliance	Statement of compliance with relevant regulations, standards and codes from suppliers; and relevant approvals from local power authorities

Focus area	Key considerations
Maintenance	Ask about the availability and expense of spare parts. Ask for information on the repairs performed under warranty and the cost of repairs.
Installation and commissioning	Information on: • potential transportation requirements for delivery of the voltage optimisation unit to site • requirements once the equipment has arrived on site (e.g. storage) • pre-installation inspections (e.g. identification of damage, breaching of protective packaging) • installation and commission requirements (e.g. who, when, how).
Acceptance testing	• Ask tenderers to outline the minimum acceptance tests that the manufacturer or supplier must run after implementation of the voltage optimisation unit. • Compare the tests proposed by several different suppliers.

Considerations when choosing a supplier

You may find it difficult to choose which supplier to use. The considerations described in Table 10 will help you.

Table 10: Considerations when choosing a supplier

Focus area	Key considerations
Reputation	Some suppliers may have better reviews and referrals than others. You may want to think about the supplier's reputation to give you confidence engaging them. Research the marketplace for independent reviews on a variety of suppliers.
Referees	Ask for referees from other businesses who have used the product. Get feedback on their experience.
Pricing	Consider the price of each different type of voltage optimisation unit. Consider the total cost of ownership and potential savings from the unit, rather than just its upfront price.
Guarantees	Some suppliers may offer guarantees on the savings that can be achieved. You should learn more about how suppliers intend to calculate the guaranteed savings.
Warranties	Some suppliers offer warranties for different time frames and inclusions. You should take note of any warranty exceptions that are unclear.

Tips

It can be hard to assess key differences between the options offered by similar voltage optimisation suppliers.

Think about the following so that you can compare them:

- the energy consumption breakdown by equipment considered
- the calculation methodology assumptions
- the voltage supplied on site
- the voltage sensitivity of the equipment on site
- the risks and mitigation strategies proposed by suppliers
- use of a bypass switch and triggering mechanism
- installation considerations and requirements
- proposed (if any) monitoring and verification of the potential savings.

CASE STUDY – Step 4: Procure

A voltage optimisation supply company collapses

Overview of the project

A local council assessed their suitability for voltage optimisation at several of their sites. This resulted in the installation of seven voltage optimisation units.

The council recognised the benefits of understanding, evaluating and assessing a site's suitability for voltage optimisation before engaging suppliers to procure a unit.

Voltage optimisation implementation

The council engaged a supplier to install a voltage optimisation unit at one of their facilities. The benefits from the implementation of the voltage optimisation unit included a substantial reduction in energy consumption.

On the basis of these figures, the organisation proceeded with the installation of two additional units at other facilities. Although the new sites did experience energy consumption savings, these savings were not as substantial as the one achieved with their first unit.

Complications with the voltage optimisation units

After the installation of the two newer units, several problems were encountered. Initially the voltage optimisation supplier was able to help with repair and maintenance of the units, but then unexpectedly the supplier's manufacturer folded, resulting in the termination of warranties, guarantees and technical support. Within 18 months of the first unit being installed, all three voltage optimisation units had developed faults. Because of a lack of spare parts the faults could not be repaired.

Outcomes

The council engaged other suppliers and continued to implement voltage optimisation at other sites. To make sure that their previous experience did not repeat itself, the council made sure that in the procurement process they would:

- enquire about the long-term stability and reputation of suppliers and manufacturers
- ask for credentials and references regarding the quality of the units and how they operated
- ask about the availability of spare parts and the lead times
- assess the ability of the supplier to support problems for the entire warranty period.

After considering the abovementioned points, the council engaged a different supplier who has installed several new units.

Note that this council's experience doesn't reflect that of all suppliers in the industry.

Step 5: Implement

Step 1 Understand | Step 2 Evaluate | Step 3 Assess feasibility | Step 4 Procure | **Step 5 Implement**

- Pre-installation considerations
- Post-installation considerations
- Manage risks

This is the final step of the decision-making process. This step gives you some high-level pre- and post-implementation considerations that will support you in successfully implementing voltage optimisation.

This step is a technical, and often a complex one, frequently involving approval and sign-off from different stakeholders (e.g. the local distribution network inspector).

This step usually needs careful planning and project management, as the power will need to be turned off on site. Installation work is often done at night to minimise disruption to site operations. Particulars of the site must be considered, such as the on-site electricity generation (e.g. solar photovoltaic, cogeneration), potential metering requirements and alterations to existing metering.

It is preferable for you to get an energy specialist to help you through this step.

Tips

To get an accurate idea of the electricity consumption impacts on your site, do your measurement and verification before voltage optimisation is installed.

You should continuously manage risks by revisiting your risk register and applying mitigation strategies.

Pre-installation considerations

Consider performing the things listed in Table 11 to help prepare the site before installation.

Table 11: Pre-installation considerations

Activity	Considerations
Measurement and verification	Measurement and verification is the process of using measurement to reliably determine actual differences in such factors as electricity consumption, demand changes and costs resulting from the implementation of an energy initiative. OEH has a Measurement and Verification Operational Guide, which is available at: www.environment.nsw.gov.au/energyefficiencyindustry/confirm-energy-savings.htm. Also, the NSW Energy Savings Scheme, administered and regulated by the Independent Pricing and Regulatory Tribunal (IPART) has a Project Impact Assessment with Measurement and Verification (PIAM&V) method. The PIAM&V method uses internationally recognised best practice M&V principles. The PIAM&V method rigorously verifies energy savings and generates Energy Savings Certificates. See **Appendix 5** for more information on the Energy Savings Scheme or go to: www.ess.nsw.gov.au/Methods_for_calculating_energy_savings/Project_Impact_Assessment_with_MV More information on Measurement and Verification can be found in **Appendix 6**.
Installation plan	Consider developing an installation plan to help make sure that installation is completed in a safe and successful way. Consider the previously assessed information on pre-implementation requirements (see the section on 'Pre-implementation requirements' in this Guide). The installation plan should help with: • monitoring contractual performance • determining the roles and responsibilities of all stakeholders • planning the role of each stakeholder as part of the installation process • managing the relationship with stakeholders • managing financial aspects of the installation process. Consider developing verification activities to be done as part of the implementation of voltage optimisation. These activities should be agreed on between the relevant stakeholders (e.g. the voltage optimisation supplier and installer). An installation checklist can be found in **Toolkit 6**.

Post-installation considerations

Consider performing the things listed in Table 12 after installation.

Table 12: Post-installation considerations

Activity	Considerations
Measurement, monitoring and verification	• perform verification on measured data to make sure that the claimed savings have been achieved • continue to monitor the electricity consumption at your site • consider monitoring performance, particularly during the defects and warranty period of the equipment • consider seasonal variations and internal activities (e.g. increases in operational hours) that may affect electricity consumption
Maintenance	• consider the maintenance requirements of the voltage optimisation units (e.g. periodic inspections, cleaning and testing) • make sure maintenance activities are formally planned and scheduled

Example of calculating post-installation considerations

A facilities manager calculated the potential maintenance costs of a voltage optimisation unit. A probability and cost methodology was used to estimate the potential costs over a 5-year period. On the basis of the estimate, the business budgeted to spend $3,700 in maintenance costs over the 5-year period.

Maintenance type	Expected cost	Probability	Times per year	Sub-total
Servicing	$0	0	0	$0
Inspection	$200	100%	2.0	$400
Cleaning	$100	80%	4.0	$320
Spare parts	$500	20%	0.2	$20
Potential yearly cost				**$740**

Note: Maintenance costs will vary depending on your business and the unit type and supplier.

CASE STUDY – Step 5: Implement

When planning your installation yields positive results

Overview of the project

The local council presented in 'Case Study – Step 4: Procure' continued to use voltage optimisation as an energy- saving initiative. As a result of its previous procurement experience, the council implemented a comprehensive evaluation process to assess potential suppliers.

To ensure the success of the voltage optimisation units, the council:

- shut the sites down overnight to give the installers enough time to install and test the voltage optimisation unit (e.g. at one of the sites, installation was done every night over a week, thus minimising the disruption of day-to-day activities)
- organised an installation team consisting of an energy specialist, an internal senior electrical engineer and organisation representatives
- made sure that installation team supervised the installation and testing of the units.

Outcomes

Installation of the units was successfully completed. Since the installation, the facilities have experienced lower electricity costs and reduced maintenance costs. The council successfully implemented voltage optimisation at their sites as a result of:

- effectively understanding, evaluating and assessing the electrical infrastructure (e.g. loads) at each of the sites
- selecting a suitable voltage optimisation unit for the site
- comprehensively assessing potential suppliers
- planning the installation of the voltage optimisation units
- employing independent professionals to oversee the installation and testing of the units.

Appendices

Appendix 1: What is voltage?

Voltage is the difference in potential energy per unit charge between two points in an electrical system. If an electrical system has high voltage, there is greater potential for the electric charge to flow through the system. Conversely, if an electrical system has low voltage there is less potential for the electric charge to flow through it.

A common way to describe voltage is to compare it to water pressure in a pipe. Pressure (i.e. voltage) allows the water (i.e. electric charge) to flow (i.e. current). Any change in the voltage will affect the ability of the electric charge to flow through the system (see Figure A1.1).

Voltage within an electric system is subject to losses (i.e. the voltage will drop as the electricity travels through an electrical circuit). Consequently, the voltage will vary within different points of an electrical network or circuit.

To understand how voltage optimisation may benefit your site, the following sections will give you an overview of how electricity is supplied to your site and the role voltage plays.

Supplying electricity

Figure A1.1: Basic concepts of voltage in an electrical system

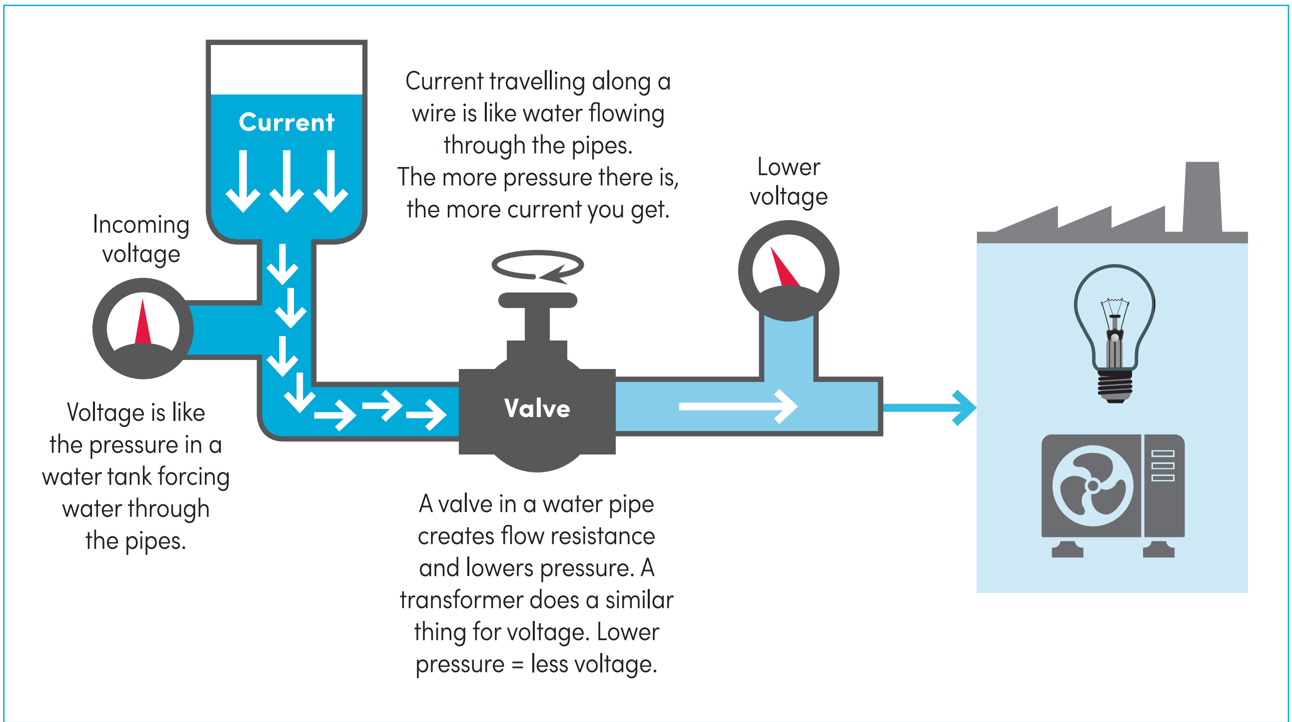


Figure A1.2 provides a schematic of the electricity supply chain.

Figure A1.2: Supplying electricity

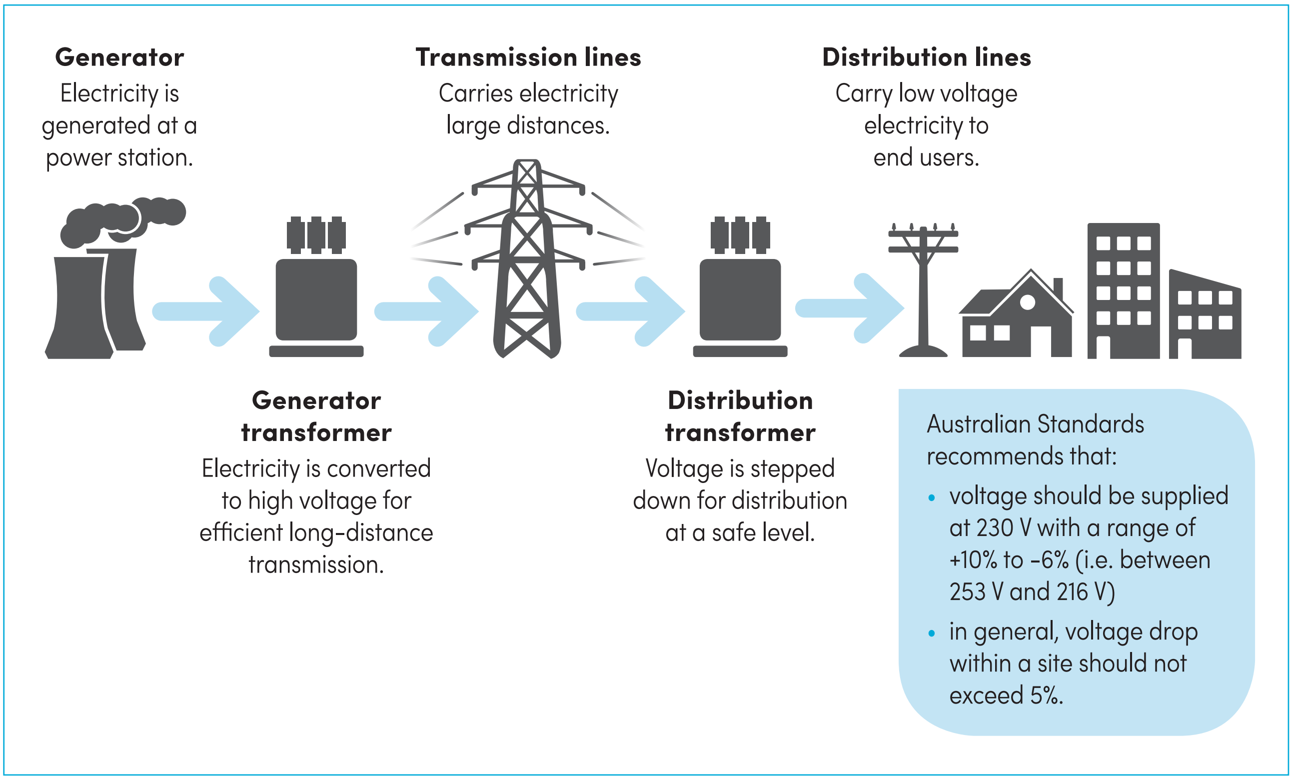


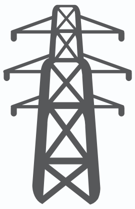
Figure A1.3 provides an overview of the various stages within the electrical network and how voltage is influenced.

Figure A1.3: The electricity network – an overview

Stage 1: Generation

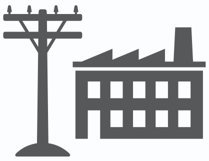
- Power stations generate electricity, which is transformed to high voltage (6,600 V to 33,000 V) (i.e. 6.6 kV to 33 kV).

Stage 2: Transmission



- To enable the transmission of electricity over long distances, transformers increase the voltage to 66, 110, 132, 220, 275 or 500 kV.
- High-voltage transmission is often needed to reduce the effect of energy losses (e.g. losses associated with wire heating over long distances).

Stage 3: Distribution



- Voltage is reduced to levels suitable for distribution (e.g. about 230 V) to operate electrical equipment and appliances.
- Larger sites (e.g. industrial sites, large manufacturers) may need higher voltages (e.g. 6.6, 11, 22 or 33 kV).

- Electricity network operators supply electricity at a voltage suitable for all end-users. This includes consumers at the 'end of the line'.
- Network operators often use transmission and distribution voltage regulation equipment (not to be confused with voltage optimisation) to manage voltage. Equipment such as tap-changing transformers and capacitors are used to increase or decrease voltage supply.
- Network operators often supply more voltage than required as a precautionary measure to avoid supply brownouts and to supply electricity at voltage levels within industry standards.

Stage 4: End user

- In general, when electricity reaches your site, Australian Standards stipulates that the voltage drop allowable in the electrical system (e.g. within your site) should not exceed 5%.

- Electrical equipment designers configure their equipment to operate within the recommended voltage rating of 230 V (in a range of +10% to -6%).

Voltage supply standards in Australia

Standards Australia developed AS 60038 to provide guidance on voltage levels for electrical supply systems. AS 60038 recommends that voltage should be supplied at 230 V (within a range of +10% to -6%). This is equivalent to an allowable voltage supply range between 253 V and 216 V.

These standards influence the way an electrical system or equipment is designed (i.e. an electrical equipment designer can choose the optimum voltage level for operating an electrical appliance).

Previous standards recommended a nominal voltage for electrical supply of 240 V. Therefore, older equipment at your site may be designed to operate at 240 V rather than 230 V.

Table A1.1 lists some of the common characteristics and problems associated with changes in voltage levels.

Table A1.1: Characteristics and problems associated with voltage

Voltage level		Characteristics/Issues*
253 V and more	**OVERVOLTAGE** Overvoltage is excess voltage. It is commonly characterised by power swells or surges.	• electrical equipment overheating • electrical circuit failure: tripping of protection system or insulation failure • reduced equipment operating life • consequences such as production and operation issues
About 230 V	**NORMAL VOLTAGE**	• efficient operation of electrical equipment as a result of operating with the designed voltage range • reduced likelihood of electrical equipment failure • reduced likelihood of production, operational and maintenance issues
216 V and less	**UNDERVOLTAGE** Undervoltage is a loss of voltage. It is commonly characterised by power sags or dips.	• lack of sufficient power to operate electrical equipment • increased current in alternating current (AC) motors • electrical circuit failure, leading to overheating • reduced equipment operating life • consequences such as production and operation issues

* Characteristics/issues depend on the severity and duration of the over or under-voltage event.

Key electricity concepts

Key points

- The power required to operate electrical equipment depends on the voltage, current and resistance.
- Electrical equipment has different voltage ratings, depending on the type of equipment, its application and its design specifications.

To understand how a change in voltage will affect your electricity consumption and costs, you need to understand the relationship between voltage, power and resistance (Table A1.2).

Table A1.2: Relationship between voltage, power and resistance

Concept	Description
Power and resistance	Electrical power is the rate of doing work and is measured in watts (W). One watt equates to one joule of energy used per second. Resistance is a measure of how easy current flows through an electrical system. Considering the water pipe analogy, the resistance is the equivalent to friction. Power is the relationship between voltage (V) and resistance (Ω). The following equation illustrates this relationship: $\text{Power (W)} = \frac{\text{Voltage (V)}^2}{\text{Resistance }(\Omega)}$
Energy consumption	Whereas power reflects the rate energy required to operate electrical equipment, electricity consumption, measured in kilowatt hours (kWh), represents how much power or energy is consumed over time. Electricity consumption (kWh) = Power (kW) x Hours (h) Energy you consumed over a period of time is measured by electricity retailers. You are charged for the electricity you consumed over a period of time (e.g. monthly or quarterly). Consequently, reducing the power delivered to or required by your electrical equipment may lead to a decrease in energy consumption and costs.
Load	The load, measured in watts (W), refers to the power required to operate an appliance at any given time. The energy consumed by the load will depend on the length of time for which the appliance is consuming power.

For certain loads, reducing voltage can reduce the power consumed. A common example is in equipment with a linear resistive load, such as incandescent lamps. Note that power consumption of some equipment is less affected by changes in voltage. These types of equipment are considered to be non-sensitive to normal fluctuations in voltage (refer to the next section).

The example in the box shows how a voltage decrease could reduce your consumption of electricity for a single piece of equipment.

SIMPLIFIED EXAMPLE: How optimising voltage can reduce electricity consumption

This example is a simple illustration of how voltage changes affect a linear resistive incandescent lamp. Considering the operation of the incandescent lamp with and without voltage optimisation, the calculation assumes that:

- The cost of electricity is $0.35 c/kWh.

Scenario 1: Without voltage optimisation

The incandescent lamp is supplied with electricity at 245 V.

The annual cost of running an incandescent lamp for 10 hrs a day, 5 days a week are $60.69 without VO compared to $53.48 with VO.

The calculation goes like this:

$$\text{Power (W)} = \frac{\text{Voltage (V)}^2}{\text{Resistance }(\Omega)}$$

$$\text{Power (W)} = \frac{(245\text{ V})^2}{900\ \Omega} = \frac{60{,}025}{900\ \Omega} = 66.7\text{ W}$$

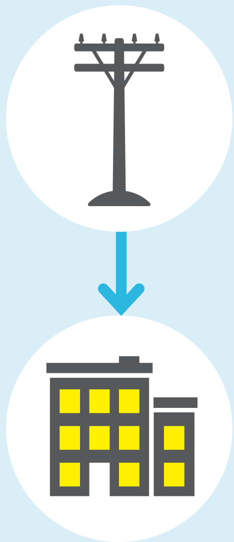
$$\text{Power (kW)} = \frac{66.7\text{ W}}{1000\ \frac{\text{W}}{\text{kW}}} = 0.067\text{ kW}$$

$$\text{Energy (kW)} = 0.067\text{ kW} \times 10\ \frac{\text{hours}}{\text{day}} \times 5\ \frac{\text{days}}{\text{week}}$$

$$\times 52\ \frac{\text{weeks}}{\text{year}} = 173.4\ \frac{\text{kWh}}{\text{year}}$$

$$\text{Cost (AUD\$)} = 173.4\ \frac{\text{kWh}}{\text{year}} \times 0.35\ \frac{\text{AUD\$}}{\text{kWh}}$$

$$= 60.69\ \frac{\text{AUD\$}}{\text{year}}$$



Scenario 2: With voltage optimisation

A voltage optimisation unit adjusts the level of the voltage supplied to the incandescent lamp to 230 V.

The calculation goes like this:

$$\text{Power (W)} = \frac{\text{Voltage (V)}^2}{\text{Resistance } (\Omega)}$$

$$\text{Power (W)} = \frac{(230\text{ V})^2}{900\ \Omega} = \frac{52{,}900}{900\ \Omega} = 58.8\text{ W}$$

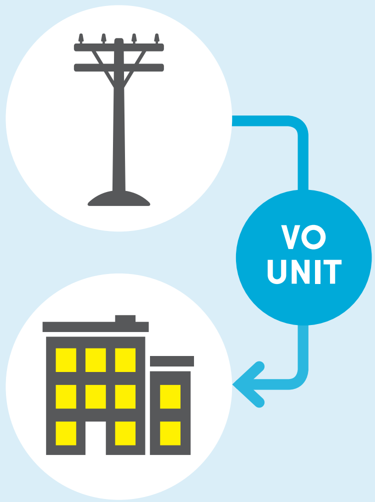
$$\text{Power (kW)} = \frac{58.8\text{ W}}{1000\ \frac{\text{W}}{\text{kW}}} = 0.059\text{ kW}$$

$$\text{Energy (kW)} = 0.059\text{ kW} \times 10\ \frac{\text{hours}}{\text{day}} \times 5\ \frac{\text{days}}{\text{week}}$$

$$\times 52\ \frac{\text{weeks}}{\text{year}} = 152.8\ \frac{\text{kWh}}{\text{year}}$$

$$\text{Cost (AUD\$)} = 152.8\ \frac{\text{kWh}}{\text{year}} \times 0.35\ \frac{\text{AUD\$}}{\text{kWh}}$$

$$= 53.48\ \frac{\text{AUD\$}}{\text{year}}$$



Result

As a result of the reduction in voltage, the cost saving from operating the incandescent lamp at 230 V instead of 245 V (based on the operating times mentioned above) is **AUD$7.21 a year.**

Note that in the particular case of an incandescent lamp, voltage optimisation will also result in a reduction in brightness. These and other considerations will be covered in greater detail in the decision-making steps.

Equipment voltage sensitivity

Key points

- An electrical appliance's power rating is the optimum power required for the appliance to operate effectively.
- Electrical equipment can be broadly categorised as being **voltage sensitive** and **voltage non-sensitive**.

Power ratings and recommended voltages

All electrical devices have a power rating, which is measured in watts or volts-amperes. The power rating is the optimum power required for the equipment to operate effectively. Electrical equipment manufacturers design their equipment to function at a voltage range (e.g. within a range of 225 V to 245 V) to enable it to operate effectively.

Figure A1.4 shows an example equipment name plate from which you can locate and record the rated power and recommended voltage requirements

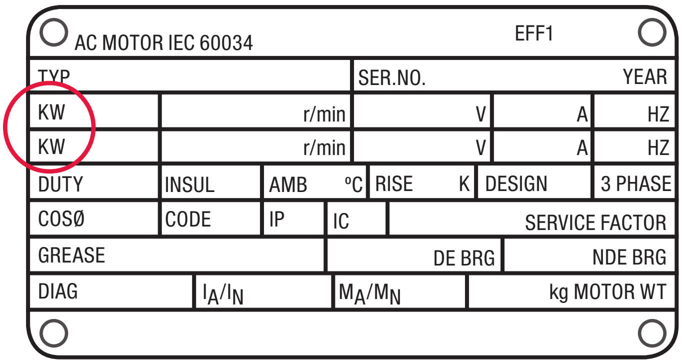


Figure 1.4: Where to find the rated power on an equipment nameplate

The recommended voltage varies between equipment and may be influenced by for example:

- the type of equipment (e.g. motors, pumps, lighting) and its size
- the power rating of each equipment
- the operation of the equipment (e.g. continuous versus stop-start operation)
- the relevant performance standards and electricity rulings (e.g. voltage standards can differ depending on the geographical location and where the equipment was manufactured and installed)
- the equipment design.

Appendix 2: How is voltage managed?

For the purposes of this guide, voltage optimisation is considered to be part of voltage management (Figure A2.1). Depending on how voltage may affect the operations, productivity and performance of your asset, voltage management may include:

- voltage stabilisation (e.g. manages electrical transients)
- voltage regulation (e.g. controls over and undervoltage)
- voltage reduction (e.g. reduces voltage by a selectable percentage)
- voltage optimisation (e.g. adjusts voltage to a certain optimal range).

Figure A2.1: Voltage optimisation is part of voltage management, which in turn is one of the many components of power quality management

Power quality management

Voltage management ▶	**Voltage optimisation ▶**	
Wave distortion – harmonics	Phase voltage imbalance	Over voltage
Transients	Voltage stabilisation	Under voltage
Frequency variation	Voltage regulation	Voltage fluctuation
Power factor	Voltage reduction	
Reactive power		
Equipment maintenance		

Introducing voltage optimisation

- A number of voltage optimisation technologies are available in Australia.
- Voltage optimisation should make sure that an appropriate level of voltage is supplied to operate equipment.
- At a site that is supplied with a higher voltage than required, voltage optimisation technology may help to reduce energy consumption, maximum demand and costs.
- Make sure you understand your electrical equipment before you implement voltage optimisation.

A key reason for developing voltage optimisation technology was to minimise damage caused to equipment by operating at voltage levels above or below the equipment's power ratings. Therefore, voltage optimisation can help reduce maintenance requirements and increase the operating life of some equipment.

Voltage optimisation technology aims to adjust the supply voltage (which is in the range of 253 V to 216 V) to a specific voltage bandwidth (e.g. 230 V or 220 V ±1%). The section below on 'types of voltage optimisation units' highlights common types of voltage optimisation units and how they work.

Some of the potential benefits of voltage optimisation are:

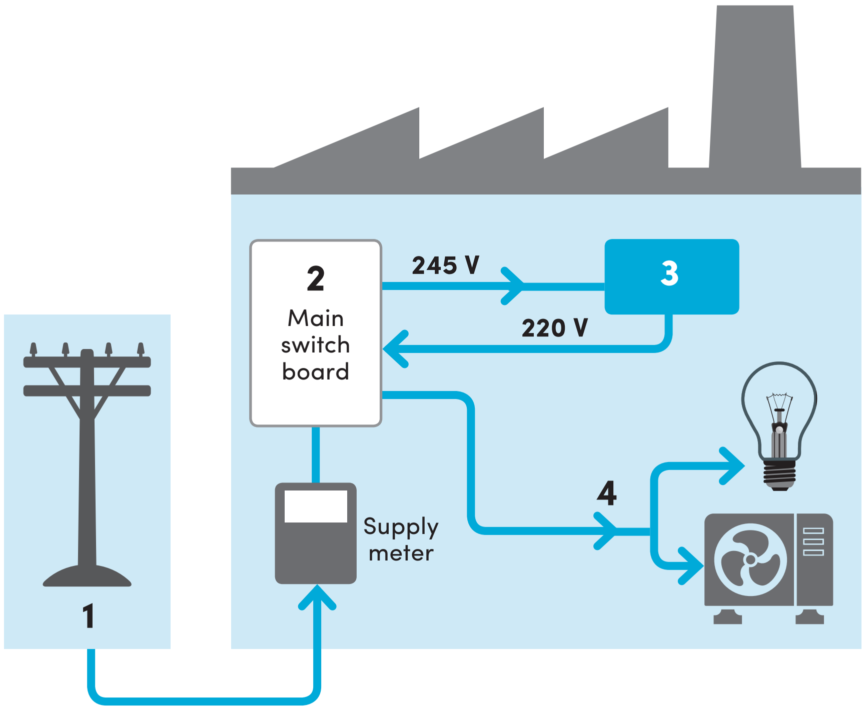
- optimum voltage levels are supplied to equipment
- it reduces electricity consumption by certain voltage-sensitive equipment and consequently reduces indirect greenhouse gas (GHG) emissions
- there is an overall increase in the lifetime of electrical equipment
- it can potentially reduce maintenance frequency, effort and cost
- it can improve overall power quality (e.g. reduce voltage feedback, reduced overvoltage, lower levels of harmonics and prevention of transients; this will depend on the type of voltage optimisation technology implemented).

Types of voltage optimisation units

There are currently three types of voltage optimsation units on the market in Australia, fixed, dynamic and dynamic system boosted.

Figure A2.2 shows how voltage optimisation units fit in with the system of power supply to appliances. Table A2.1 gives information on some of the common types of voltage optimisation units.

Figure A2.2: Use of a voltage optimisation unit in the power supply system



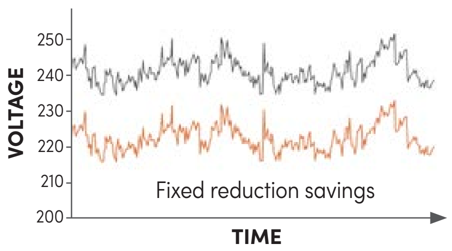
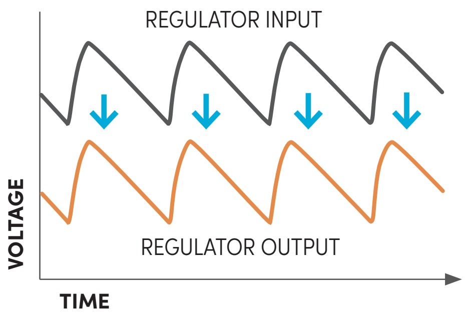
1. Power to the site
The grid voltage enters your site at an average of 245 V.

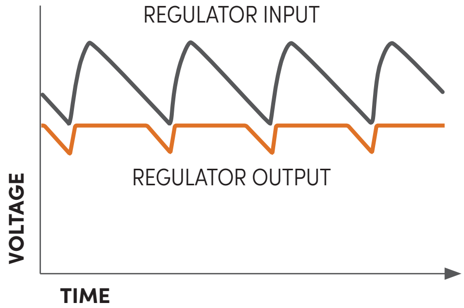
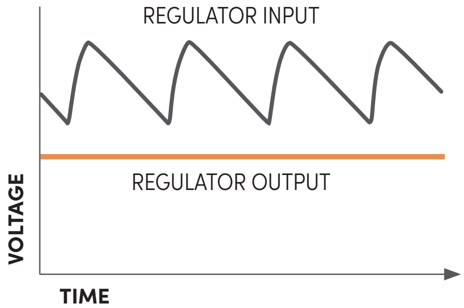
2. Main switch board
Modern consumer units have a split load arrangement.

3. Voltage optimisation
The voltage optimisation unit steps down the voltage from 245 V to 220 V.

4. Power to equipment
The lower 220 V electricity feeds selected lighting and equipment at your site potentially saving you electricity and GHG emissions.

Table A2.1: Common types of voltage optimisation units and their disadvantages and advantages

Type	Description	Benefits	Issues
Fixed voltage regulators  	Fixed voltage regulators are basic voltage optimisation units that step down voltage by a fixed amount (e.g. 5%). The units deliver a varying output (i.e. with the same variation as the supply) at a lower voltage than the supply. These units use magnetic couplings that transmit an electrical load and use a secondary winding that applies an induced opposing voltage. They do not reactively adjust to voltage supply levels.	Generally cheaper than dynamic systems. Small units. Ideal for sites where voltage supply levels are relatively stable.	Does not actively compensate for voltage fluctuations in the supply. Risk associated with undervoltage (i.e. these units may supply voltage that is lower than the rated voltage in the event of a dip in voltage supply).

Type	Description	Benefits	Issues
Dynamic system voltage optimisers 	Voltage optimisers aim to dynamically adjust voltage levels within a specific range. This output is aimed at supplying a specific voltage required by certain electrical equipment. Most voltage optimisers use electronic controls that can adjust voltage within a specified bandwidth. This is achieved by continually comparing the incoming voltage with the voltage needed to drive the loads. Some voltage optimisers may also contain features to address other power management elements such as harmonics, transients and power factor.	Voltage optimisers are used to adjust the supply voltage to a more precise and steadier level. This enables the user to supply voltage closer to the equipment's power rating, resulting in greater energy savings.	Voltage optimisers are typically more expensive than voltage regulators. They do not compensate for voltage drops in the supply. (Some voltage optimisers have protection against voltage drop.) Depending on the unit, voltage optimisers are generally larger than voltage regulators.
Dynamic system boosted voltage optimisers 	These electronically controlled voltage optimisers are capable of boosting voltage to safeguard voltage supply in the event of voltage drops.	Generally used when the voltage drops regularly below the desired level. May be suitable for end-users with a variable voltage supply.	Additional costs for the voltage booster. Not widely used in Australia, as the voltage does not usually drop to levels below the minimum allowable level (i.e. 216 V).

Alternatives to managing voltage

There are a number of alternatives to managing voltage. They include the following:

- If under or over-voltage is a potential issue at your site, consider, for example:
  - performing a detailed power quality assessment
  - implementing load balancing initiatives
  - installing power conditioning equipment
  - retrofitting equipment with wider voltage tolerance equipment or non–voltage sensitive equipment
  - installing under or overvoltage protection equipment.
- In the case of high-voltage and medium-voltage sites with onsite utility transformers, you can request the electricity supplier modify the voltage from the incoming transformer.

Appendix 3: Potential issues

Table A3.1 below provides examples of the common issues and risks that you could encounter when considering the viability of voltage optimisation. Importantly, the table has been developed for guidance purposes only. Each site will have unique characteristics that will need to be considered and you should perform a site-specific risk assessment. As voltage optimisation assessment progresses through each of the steps, you should keep an issues register and update it to make sure that risks are identified, qualified and mitigated.

Table A3.1: Common issues and risks associated with considering voltage optimisation

Issue	Description
Site issues and risks	
Site plans/ strategies	Changes to a site such as operational improvements, life-of-asset changes, production variability or changes to lease periods may affect the feasibility of installing a voltage optimisation unit. The impacts of voltage optimisation should be considered against current and future site plans and strategies for your business and your site. This is important, as it may affect energy- and cost-saving expectations.
Equipment upgrades	Equipment upgrades, retrofits, replacements etc. may affect the effectiveness of voltage optimisation. Examples are: • replacement of an uncontrolled inductive motor with an efficient motor controlled by a VSD • upgrade of voltage-sensitive magnetic ballast lighting to voltage-non-sensitive LEDs. Voltage optimisation should be considered against future plans for the site, including equipment upgrades. When considering voltage optimisation, make sure that planned equipment maintenance and replacement schedules are considered as part of the decision-making process.
Overvoltage	Overvoltage is excess voltage characterised by swells or surges in the electrical circuit. Depending on the length of time of the event, it may cause: • electrical equipment overheating • electrical circuit failure (e.g. tripping) • reduced equipment operating life • production and operation impacts. See the section on ‘Supplying electricity’ for potential issues. When you are considering voltage optimisation it’s important that you understand your present voltage supply levels and note any voltage issues associated with the site.
Undervoltage	Undervoltage is a loss of voltage, characterised by sags or dips in the electric circuit. Depending on the length of time of the event, it may cause: • lack of sufficient power to operate electrical equipment • reduced motor torque • electrical circuit overheating • reduced equipment operating life • production and operation impacts. See the section on ‘Supplying electricity’ for potential issues. When you are considering voltage optimisation it’s important that you understand your present voltage supply levels and note any voltage issues associated with the site.

Issue	Description
Voltage optimisation issues	
Security of supply	Voltage optimisation units are positioned upstream of an electrical circuit that supplies electricity to an entire site or to a specific area. If a failure occurs in the voltage optimisation unit, your business can be substantially affected by equipment downtime. Redundancy measures should be considered to mitigate this risk (e.g. by installing a bypass switch).
Sizing	Selecting a voltage optimisation unit that is the wrong size for the application may lead to equipment failure. A key feature of doing a detailed feasibility assessment is to work out the sizing requirement of the voltage optimisation unit (typically measured in kVA).
Savings/benefits	Benefits and savings should be clearly understood to manage expectations. A lack of understanding of the site loads and voltage sensitivity may lead to uncertainty about the benefits of voltage optimisation.
Feasibility assessment	Make sure that experienced and qualified personnel are involved in the decision-making process and can test the suitability of voltage optimisation. Use an in-house or independent specialist to determine the feasibility of the technology and to develop specifications for the site (e.g. size and location of unit).
Ownership	Lack of ownership of the project within the organisation may increase the risk associated with the implementing voltage optimisation. Where possible, allocate accountability and responsibility to personnel during all steps in the voltage optimisation project. This should include post-implementation activities such as monitoring and verification, inspections, and testing.
Alternative options	The assessment of voltage optimisation should be balanced and should consider alternative measures so that you can make an informed investment decisions. For example, a site may achieve greater benefits through other technology upgrades, such as the installation of VSDs on motors or lighting upgrades.
Fixed regulators	In the event of voltage drops, a fixed regulator may reduce the supply voltage by a fixed percentage. This may create undervoltage events. Voltage boosters may be needed, which may cost more.
Installation	To install a voltage optimisation unit the electrical circuit must be isolated. Make sure you have contingency plans when planning the installation. For example, backup power is typically required for emergency systems or for refrigeration units containing perishables. If the installation is longer than planned, your site's operations will be affected. The planning should also consider the need to test downstream equipment and to make sure that operating equipment returns to a steady state after the installation.
Operations	Examples of operational issues are: • A voltage optimisation unit may fail, causing operational disruptions. A mitigation strategy commonly employed is the installation of a bypass switch. • An undervoltage event (e.g. voltage below the recommended equipment ratings) may occur, causing equipment damage. This can be mitigated by installing a voltage booster.

Issue	Description
Maintenance	Set up a maintenance regime to make sure that the voltage optimisation unit is performing to the business's expectations and to mitigate potential issues. Although voltage optimisation units typically require minimal maintenance, the units (and consequently your site) may need to be de-energised so that maintenance can be done. Important: Inspections should be done only by suitably qualified personnel and in accordance with relevant internal and external requirements.
Supplier	Voltage optimisation supplier issues may include: • financial strength and longevity of the business • warranty and guarantee conditions • technical support in Australia or NSW • lead times for support services (e.g. spare parts availability) • defect liability period • compliance with legislative requirements and standards • financial strength of the business • proven track record.

Appendix 4: Scenario planning

Tables A4.1 and A4.2 give examples of common suitable and unsuitable scenarios you might encounter when implementing voltage optimisation. The tables have been developed for guidance purposes only. Your site will have unique characteristics and challenges that will need to be considered. A site-specific risk assessment should be done to examine possible scenarios and risks.

Table A4.1: Scenarios potentially suitable for voltage optimisation

Scenario	Reasoning
Your site has a high proportion of voltage-sensitive equipment.	Sites with a high proportion of voltage-sensitive equipment are the most likely to reduce their energy consumption and costs.
Most of the electricity is consumed by voltage-sensitive equipment.	If most of the energy is consumed by voltage-sensitive equipment, your site may benefit from voltage optimisation, leading to a reduction in energy and associated costs.
Your site has a large number of motors (e.g. HVAC and refrigeration).	Partial loading of motors can result in energy losses. Adding a voltage optimisation unit may give energy savings.
Upgrading voltage-sensitive equipment would involve a large amount of capital expenditure.	If the payback period of alternative opportunities is high, then voltage optimisation may be a viable energy-saving opportunity.
Your site has expensive voltage-sensitive equipment.	Voltage optimisation has potential benefits in reducing the maintenance costs of certain equipment. Some sites may value voltage optimisation for this reason over its energy-saving potential.

Table A4.2: Scenarios potentially unsuitable for voltage optimisation

Scenario	Reasoning
Your site has one group of voltage-sensitive equipment consuming most of the electricity.	If one type of equipment is using a substantial percentage of the total electricity consumed, it may be more beneficial to upgrade the equipment than to install a voltage optimisation unit.
Your site uses mainly voltage-non-sensitive equipment.	Savings from installing a voltage optimisation unit may be small if a high proportion of the equipment is non-sensitive to normal voltage changes.
The business may not be at the site for an extended period of time.	If the business has plans to move in the immediate future, the benefits of voltage optimisation may be limited.
The business is considering other energy efficiency upgrades.	If the business installs new energy-saving equipment concurrently, then it will be hard to assess the impact of voltage optimisation. Additionally, changes in the equipment on site (e.g. upgrades) may decrease the overall sensitivity of the site to voltage optimisation.

Appendix 5: Financing voltage optimisation

A variety of energy efficiency and renewable energy financing options are available to NSW businesses. These options generally fall into four categories (Figure A5.1).

Figure A5.1: Financing options for voltage optimisation

Note:

- For more details on how to choose the most suitable financing option for your site, refer to the OEH Energy Efficiency and Renewables Finance Guide (2014), available at www.environment.nsw.gov.au/resources/business/financing-guide.pdf. This guide provides a comprehensive comparison of different financing options.
- Some financing options have been excluded, as they are more than likely not relevant to voltage optimisation opportunities. They include energy efficient loans from banks; such loans are normally reserved for projects that exceed AUD$500,000 in total.

The funding options are summarised in Table A5/1.

Table A5.1: Options for funding voltage optimisation

Type	Financing option	Description
Internal	Self-funding	An energy efficiency project that is financed by using internal capital and funds. This offers no loan repayments, but it may carry greater risk for the business and may limit cash flow.
Bank Loan	Commercial loan	A loan from a financier that is repaid in regular instalments with an interest rate that changes in line with a reference lending rate. Although this loan offers reduced initial costs to the business, the customer assumes risk and may be required to offer collateral.
Lease agreements	Operating lease	A lease in which the financier owns the voltage optimisation unit but the customer has sole rights to use it. The business would have to cover maintenance and operating costs and also make regular lease payments. At the end of the lease, they have the option to continue the lease and return or buy the equipment itself. Leases involve reduced upfront costs, and leasing costs are fixed and tax deductable.
	Capital lease	A capital lease is similar to an operating lease, but the customer agrees to purchase the equipment at the end of the lease for an agreed fee. Another key difference is that the customer can depreciate the unit.
Other	Utility on-bill financing	This is where an energy retailer installs the voltage optimisation unit and the costs incurred are repaid by the customer through charges on their electricity bill. Once the payments finish, the unit becomes the property of the business. An on-bill financing method will typically guarantee savings but it may prevent you from changing energy supplier.
	Environmental upgrade agreement	This is a loan to businesses for an environmental upgrade; it is paid back to a local council via charges over time. Although the rates and terms offered are better for businesses than those of other loans, only some NSW councils offer this service.

There are funding options available to NSW businesses to encourage energy efficiency. The Energy Savings Scheme (ESS) is potentially available to businesses installing voltage optimisation. More comprehensive details can be found online at www.ess.nsw.gov.au.

High-level information from the ESS is provided in Table A5.2.

Table A5.2: Details of the Energy Savings Scheme

Description	Criteria
The Energy Savings Scheme (ESS) is an incentive program to encourage businesses to invest in energy savings projects. The scheme provides Energy Savings Certificates (ESCs) for every megawatt hour (MWh) you save from a new project. These certificates are sold to liable parties such as electricity retailers, who must meet legislative targets generating profit for the ESS participant. Businesses can choose to either calculate their savings themselves and sell ESCs or allow existing accredited certificate providers to handle their savings records. The ESCs are sold on an open market, so prices will fluctuate regularly. The value of the scheme is also directly related to your total energy savings. However, if you are receiving large energy savings from your voltage optimisation it is likely that the ESCs will provide moderate benefits over the equipment's lifespan. Even if the energy savings you receive are below what was expected, the scheme represents 'money on the table' that is there if you are willing to measure and verify your savings.	The ESS is typically available to: • businesses that are implementing an energy savings project (excluding investments that use only renewable energy) • businesses that are not required by legislation to implement the energy savings investment. The value of participating in the ESS depends on the total energy savings gained by installing the voltage optimisation unit and the market price of ESCs at that time.

Appendix 6: Measurement and verification

Measurement and verification (M&V) is the process of using measurement to reliably determine the actual savings on energy, electricity demand, cost and greenhouse gas (GHG) emissions within a site by using an energy conservation measure (ECM).

Instead of applying deemed savings or theoretical engineering calculations based on previous studies, manufacturer-provided information or other indirect data, measurements are used to verify savings. Savings are determined by comparing post-implementation performance against pre-implementation performance (i.e. a 'business as usual' forecast). M&V:

- enables you to calculate actual savings for projects that have high uncertainty or highly variable energy consumption characteristics
- can be used to verify installed performance against manufacturer claims
- gives a verified result that can be stated with confidence and can prove the return on your investment
- demonstrates performance where a financial incentive or penalty is involved (e.g. in engineering, procurement and construction)
- gives effective management of energy costs
- enables you to build robust business cases to promote successful outcomes.

OEH (2012) has prepared a *Measurement and Verification Operational Guide* (M&V Guide; www.environment.nsw.gov.au/energyefficiencyindustry/confirm-energy-savings.htm). The M&V Guide is based on the International Performance Measurement and Verification Protocol. The M&V Guide has practical tips, tools and scenario examples to help your business with decision-making, planning, measuring, analysing and reporting outcomes.

The M&V Guide consists of:

- a best practice M&V process guidebook, which provides guidance that is common across all M&V projects
- a suggested M&V planning process guidebook, which helps both new and experienced users to develop a robust M&V plan for an energy savings project by using a step-by-step process for designing an M&V project
- seven application-specific guidebooks that provide specific guidance on how to plan and conduct M&V for technologies found in typical commercial and industrial sectors. These specific sectors are:
  - boilers, steam and compressed air
  - commercial and industrial refrigeration
  - commercial heating, ventilation and cooling
  - lighting
  - motors, pumps and fans
  - renewables and cogeneration
  - whole building applications
- An M&V project planning template, which is a Microsoft® Excel tool, aims to help you to capture the key components for a successful M&V Plan.

Use of these guides and the tool may make your business eligible for government funding schemes (e.g. under the Energy Savings Scheme).

Your voltage optimisation toolkit

Toolkit 1: Types of voltage sensitivity

The voltage sensitivity of equipment can be broadly categorised into sensitive and non-sensitive (Table T1.1).

Table T1.1: Voltage sensitivity of equipment

Equipment sensitivity	Explanation
✔ **Voltage sensitive**	Power consumption and/or output of an appliance varies depending on the voltage supplied.
✘ **Voltage non-sensitive**	An appliance is designed to have a fixed power consumption and output, regardless of the voltage supplied.

Why this is important?

Understanding how voltage sensitive your equipment is will determine the potential benefits of voltage optimisation.

* The equipment items outlined in this checklist are indicative only. The voltage sensitivity of an appliance may also be impacted if it installed directly to mains power supply. Always check with an electrical professional when determining if your equipment is voltage sensitive or not.

Tip

The checklist in Table T1.2 gives examples of common types of electrical equipment and their voltage sensitivities. You can use this checklist to work out whether your equipment is sensitive to voltage or not. Although the checklist is intended as a guide to the voltage sensitivities of common electrical equipment, you should check with an energy specialist (e.g. an electrician, supplier or consultant) to confirm the voltage sensitivity of the particular equipment at your site.

Table T1.2: Equipment voltage sensitivity checklist

Equipment type	Voltage sensitivity	Notes
LIGHTING Lighting can be a significant source of electricity consumption. Importantly: • the light output of a voltage-sensitive lamp (i.e. the strength of the light emitted) is affected by the voltage level • the life expectancy of a light may be reduced if the voltage varies significantly from its power rating.		
Incandescent lamps Most incandescent lamps were designed to operate on a 240 V supply and are voltage sensitive. A change in voltage will affect the output of light (i.e. decrease the light emitted).		
	✔ Voltage sensitive	Incandescent lamps are no longer available to purchase for commercial applications, although they may still be available for decorative purposes.

Equipment type	Voltage sensitivity	Notes
Fluorescent lamps Fluorescent lamps are commonly either linear or compact. Fluorescent lamps are controlled by devices that regulate voltage. These control devices can be either: • inductive (or magnetic) ballasts • electronic ballasts, or • high-frequency controlled.		
Fluorescent lamps (inductive ballast)	Voltage sensitive	Inductive ballasts are generally copper and iron devices that have an inductor and are connected to mains voltage. These lamp fittings can be classified as voltage sensitive.
Fluorescent lamps (electronic ballast)	Voltage non-sensitive	An electronic ballast regulates the voltage and delivers a constant output. Hence fluorescent lamps with electronic ballasts are voltage non-sensitive.
Fluorescent lamps (high-frequency)	Voltage non-sensitive	High-frequency fluorescent lamps are either passively or actively electronically controlled. Actively controlled fluorescent lamps use integrated circuitry at the front end of the lamp, whereas passively controlled fluorescent lamps use drivers to regulate the incoming voltage to a higher frequency. Both of these electronic components make these lamps voltage non-sensitive.
High-intensity discharge lamps (HIDLs) Discharge lamps involve current being passed through a gas, resulting in the production of light. These lamps use: • a conventional ballast (i.e. inductive ballast) or • an electronic ballast.		
High-intensity discharge lamps (inductive ballast)	Voltage sensitive	Examples of HIDLs are: • mercury vapour lamps • sodium vapour lamps • metal halide lamps. HIDLs usually have an internal arc that is connected to mains voltage supply, making the lamps voltage sensitive.
High-intensity discharge lamps (electronic ballast)	Voltage non-sensitive	Similar to other electronically controlled lamps, HIDLs with electronic ballasts are not affected by normal voltage variations; this makes these lamps non-sensitive. The electronic ballast regulates voltage and delivers a constant output.

Equipment type	Voltage sensitivity	Notes
Induction lamps The mercury in a typical induction lamp is stimulated into producing light by the use of a magnetic field.		
	✗ Voltage non-sensitive	These lamps are operated by electronic control gear and are classified as non-sensitive to voltage.
Light emitting diodes (LEDs) LED pass electricity through a semiconductor, which produces photons (a basic unit of light).		
	✗ Voltage non-sensitive	LEDs are electronically controlled and hence are non-sensitive to normal voltage variations.

INDUSTRIAL EQUIPMENT (MOTORS)

For many industries, electrical motors can consume a significant amount of electricity on site. Alternating current (AC) induction motors are the most common type of motors. The power a motor draws is determined by the relationship between voltage and electrical current (measured in amperes).

Overvoltage

An increase in voltage may draw excess electrical current in an attempt to increase the motor's magnetic field. Therefore, overvoltage may cause overheating and a decrease in the life expectancy of the motor.

Undervoltage

When voltage is decreased, the electrical current increases in order to provide the power required by the motor. Impacts of undervoltage may include:

- a decrease in torque capability, which requires the motor to work harder to achieve the required output
- overheating, which may damage the motor
- a potential decrease in the life expectancy of the motor.

Equipment type	Voltage sensitivity	Notes
Motors: linear (fixed) speed (small)	✓ Voltage sensitive	Small motors are generally single-phase induction motors. As such, they are voltage sensitive. The starting coil will be affected by voltage reduction, resulting in the motor taking longer to reach a steady state.
Motors: linear (fixed) speed (medium to large)	✓ Voltage sensitive	Medium to large motors are generally three-phase induction motors. These types of motors do not require any special configuration to start rotating when the starter is first energised. These motors are normally less affected by voltage variations than are small motors however they are still classified as voltage sensitive.
Motors: permanent magnet (PM)	✗ Voltage non-sensitive	PM motors use magnets, rather than electromagnets, to produce the rotating force. An example of this is electronically commutated (EC) motors. These motors are normally non-sensitive to voltage, as any variation will be regulated by the electronic controls.

Equipment type	Voltage sensitivity	Notes
Motors: variable speed (controlled)	Check your site	A speed control can be used on a motor with a variable load or partial load. These controls run the motors at reduced speeds by using a variable-voltage, variable-frequency drive (VVVF). VVVFs are also commonly referred to as a variable frequency drives (VFDs) or variable speed drives (VSDs). As the control device regulates the voltage supplied to the motor, these motors are less sensitive (although somewhat sensitive) to voltage variations in the mains feed.
REFRIGERATION Refrigeration systems use motors in compressors, fans and pumps. Refrigeration systems can be complex and contain many components, which may or may not be voltage sensitive. The sensitivity to voltage of a refrigeration system depends on the type, size, age and load of the system.		
Refrigeration (uncontrolled)	Voltage sensitive	An uncontrolled refrigeration system (i.e. start–stop operation) may be voltage sensitive, depending on the type, size and operation of the system.
Refrigeration (controlled)	Check your site	Electronically controlled refrigeration units (e.g. refrigeration systems with variable-speed devices) may be considered as somewhat voltage sensitive because: • the speed of the motor is being adjusted to suit the requirements of the refrigeration system; and • some variable-speed devices are somewhat sensitive.
HEATING, VENTILATION AND AIR CONDITIONING (HVAC) Heating, ventilation and air conditioning (HVAC) systems are used to treat, condition and regulate air. HVAC uses motors to achieve temperature control; these are normally complex systems.		
HVAC (flow uncontrolled)	Voltage sensitive	Some HVAC systems rely on the mains voltage supply. In these cases, an uncontrolled HVAC system can be sensitive to voltage variations at a light load.
HVAC (inverter)	Voltage non-sensitive	Some HVAC systems use inverters to control the speed of motors to have a constant load (i.e. by using a VVVF drive). Similar to other technologies that have electronic control devices, an HVAC system that uses an inverter is generally non-sensitive to normal voltage supply changes.

Equipment type	Voltage sensitivity	Notes
Heating: coil/resistance	Voltage non-sensitive	Heating is normally controlled by a thermostat, which controls how long the heating device operates for. A heating device with a thermostat is considered voltage non-sensitive, as the thermostat controls the time the heating device operates to reach a set point and therefore uses the same amount of energy. In cases where a heating coil operates continuously (i.e. the coil is heated 24/7) the equipment will be voltage sensitive.

OTHER COMMON EQUIPMENT

There is a variety of other common electrical equipment types that are normally non-sensitive to voltage variations. These include:

- information technology equipment
- uninterruptible power supplies
- equipment that uses inverters.

Information technology (IT) equipment	Voltage non-sensitive	Most IT electronic equipment operates at a fixed voltage level, independent from the supply. Battery-powered equipment normally has a transformer to convert the mains electricity supply voltage (e.g. 230 V) to a lower voltage (e.g. 15 V). IT equipment is therefore generally considered voltage non-sensitive.
Uninterruptible power supply (UPS)	Voltage non-sensitive	UPS units are designed to provide a constant output. UPSs utilise a rechargeable battery to act as a buffer from voltage variations. As such, the equipment connected to a UPS can be classified as voltage non-sensitive.
Equipment that uses inverters (surge protection)	Voltage non-sensitive	Equipment that uses an inverter is generally non-sensitive to normal voltage variations. The voltage output from the inverter is designed to be constant. More complex inverters may allow voltage output levels to be selected to suit the specifications of the electrical device however they are overall classified as non-sensitive.

Determining voltage sensitivity

Use Table T1.3 to determine the voltage sensitivity of equipment at your site.

Table T1.3: Template for determining voltage sensitivity

Type	kWh/month	Breakdown (%)	Voltage sensitivity	
			Sensitive	Non-sensitive
Lighting				
Industrial equipment				
Refrigeration				
HVAC				
Other common equipment				
Other				
Total				

Toolkit 2: Electrical equipment/asset register template

Use Table T2.1 to record the details of the pumps, motors and lighting at your site.

Table T2.1: Template for a register of electrical equipment and assets

Attribute	Data and information
Pumps	
Type of pump	
Manufacturer	
Model number	
Serial number	
Size/dimensions	
Vendor	
Weight (kg)	
Guarantee start date	
Master warranty	
Diameter – discharge (mm)	
Diameter – impeller (mm)	
Diameter – sphere (mm)	
Diameter – suction (mm)	
Efficiency (%)	
Flow (L/s)	
Head (m)	
Mean gross head (m)	
Number of stages	
Speed (rpm)	
Weight (kg)	

Attribute	Data and information
Motors	
Manufacturer	
Model number	
Serial number	
Size/dimensions	
Vendor	
Begin guarantee date	
Master warranty	
Full load current (amps)	
Current – operating (amps)	
Frequency (Hz)	
No. of poles	
Power rating (kW)	
Speed (rpm)	
Nominal speed	
Voltage (V)	
Weight (kg)	

Lighting	
General description (e.g. use of lighting)	
Type of lamp (e.g. LED)	
Wattage rating (W)	
Quantity of luminaires	
Average weekly operating hours (h)	
Age of lights (years)	
Type of transformer	

Toolkit 3: Site/area load profile

The template in Table T3.1 will help you to work out the loads at your site. This can be done by site or by area. In the table you list the main electrical equipment and record its use throughout the month.

Table T3.1: Template for determining the loads at your site

Equipment item	Power rating (kW)	Number of units	Voltage sensitivity	Maximum load (kW)	Utilisation factor (%)	Hours/ month	Electricity consumed (kWh/ month)	Breakdown of electricity consumption (%)
Total					**NA**			**100%**

NA = not applicable

Toolkit 4: Business case template

The business case template in table T4.1 is intended to help organisations that don't have a formalised business case process to assess the need for voltage optimisation. It is based on OEH's energy auditing template. More information is available at: www.environment.nsw.gov.au/business/business-case-training.htm.

Table T4.1. Business case template

<table>
<tr><th colspan="2">BUSINESS CASE: Voltage optimisation</th></tr>
<tr><td>Detailed description</td><td>The business case should include a description of:

voltage optimisation technology
site loads summary
voltage dependency of existing equipment
business considerations
feasibility assessment
assumptions
calculations.

Voltage dependency
<table>
<tr><th>Area/equipment</th><th>Electricity consumption breakdown (%)</th><th>Voltage sensitive</th><th>Potential impact ($)</th><th>Voltage optimisation recommended</th></tr>
<tr><td></td><td></td><td>Yes/No</td><td></td><td>Yes/No</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
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</table>
</td></tr>
</table>

Operational benefits	Outline the potential benefits of the voltage optimisation project.
Risk management	Describe the main issues/risks and outline the relevant strategy/action plan to mitigate them.

Business case assumptions	Project life (years)	
	Inflation rate %	
	Discount rate for Net Present Value %	
	Fuel cost escalation rate %	

Business case results							
Electricity savings (MWh p.a.)	Energy cost savings (AUD$ p.a.)	Other cost savings (AUD$ p.a.)	Total cost savings (AUD$ p.a.)	Capital cost (AUD$)	Payback period (years)	Net present value (AUD$)	Greenhouse gas savings (tCO_2e p.a.)

Implementation plan	Outline the implementation plans or steps required to implement the voltage optimisation project at your site.

Toolkit 5: Sample decision matrix analysis

Using a decision matrix analysis (Tables T5.1 and T5.2 can help you to decide which energy opportunity is likely to be the most viable. You may want to compare several energy options and apply a weighting factor to each of them, depending on how suitable they are for meeting each assessment criterion.

First rate each energy option on a scale of zero (not suitable) to three (very suitable) against each criterion (Table T5.1).

Table T5.1: Example of using a decision matrix to rate the suitability of energy options

Energy option	Assessment criterion							
	Electricity saving (MWh] p.a.	CAPEX [AUD$]	OPEX [AUD$]	Total cost savings $ p.a.	Simple payback (years)	Greenhouse gas savings (tonnes CO_2) p.a.	Risk to existing equipment	Ease of implement-ation
Voltage optimisation	3	2	3	2	2	2	0	1
Solar photovoltaic	2	1	1	2	0	3	1	1
Lighting retrofit	2	3	3	2	2	2	3	2
HVAC replacement	1	3	0	1	1	1	2	1

Notes:

- The numbers in this example do not necessarily represent actual suitabilities for an energy-saving opportunity. The suitability of different opportunities will depend on the nature of your site.
- CAPEX, capital expenditure
- OPEX, operating and maintenance expenditure

You must then give an importance rating to each assessment criterion. A scale of 1 (not important) to 5 (very important) can be used. By multiplying the suitability factor (from Table T5.1) by the weighting factor for each assessment criterion (see the first row of Table T5.2), you obtain a weighted total, which can be used to help support decision-making.

Table T5.2: Example of using a decision matrix to determine overall energy option suitability and the importance of each assessment criterion

	Assessment criterion								
	Electricity saving [MWh] p.a.	CAPEX [AUD$]	OPEX [AUD$]	Total cost savings $ p.a.	Simple payback (years)	GHG savings (tonnes CO_2) p.a.	Risk to existing equipment	Ease of imple-mentation	Total
Importance weighting (1–5)	**3**	**5**	**3**	**5**	**5**	**1**	**4**	**3**	**–**
Energy option									
Voltage optimisation	9	10	9	10	10	2	0	3	53
Solar photovoltaic	6	5	3	10	0	3	4	3	34
Lighting retrofit	6	15	9	10	10	2	12	6	70
HVAC replacement	3	15	0	5	5	1	8	3	40

Notes:

- The weightings in this example have been determined arbitrarily. You should consider what weightings to place on each factor you assess. The results provided in this example do not represent actual suitabilities for an energy saving opportunity
- CAPEX, capital expenditure
- OPEX, operating and maintenance expenditure

These total weighted results may help show you which technology your site should focus on. In this example, the weighted matrix shows that lighting retrofit may be the best option for the business to consider. After the lighting retrofit, the second most attractive technology is voltage optimisation. You will need to weigh up which energy option you will select for further evaluation or implementation.

Toolkit 6: Installation checklist

Table T6.1 is an example of a checklist for use when installing voltage optimisation units.

Table T6.1: Sample installation checklist

Consideration	Outcome	Reasoning
Planning		
Unit delivery date	[Insert date]	Inform planning and reduce lag time. Installation will more than likely be done outside business hours.
Installation date	[Insert date]	
Time of day and duration	[Insert hours]	
Inspection		
External inspection	[Complete: yes/no]	Check for missing components, contaminants or damage (water or physical)
Internal inspection	[Complete: yes/no]	May not be feasible on some units. General inspection of interior, where possible, to ensure mechanical components look undamaged.
Resources required		
Electrical specialist (supplier-provided)	[Insert name]	Suppliers may request a specialist to install the unit.
Electrical specialist (preferred specialist)	[Insert name]	Choose your own trusted specialist to oversee the installation.
Business representative	[Insert name]	Having a representative can improve accountability if there are issues with installation.
Others (e.g. Health and Safety Officer)	[Insert name]	There may be other important parties needed to oversee the installation.
Testing		
Test unit	[Working: yes/no]	Check for evidence of correct operation.
Test on-site equipment	[Working: yes/no]	Check for evidence of under-voltage (lights flickering, low motor performance).
Test bypass switch	[Working: yes/no]	Check to see if the unit can be successfully overridden (if installed and if possible).