Voltage Optimisation Guide for the Meat Processing Industry

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1. Introduction

1.1. Background

Energy costs are one of the major operating expenses in the meat processing industry ($AUD1M to $AUD2M per year each in the top 25 processing plants in Australia) with primary energy sources including electricity and natural gas. In a meat processing facility electricity is predominantly used for refrigeration, compressed air and lighting while gas is used for hot water and steam systems[1]. All electrical and electronic systems are designed and manufactured to operate at maximum efficiency with a given supply voltage, called the *nominal operating voltage*. Electricity supply voltage, which is maintained by the network operator, is usually higher than the optimum (nominal) operating voltage required for most of the equipment in facilities. A facility's voltage supply can also suffer from voltage surges, over voltage (spikes), under voltage (sags), as well as power factor and harmonic losses.

To ensure adequate power quality and reduce energy costs it is beneficial to maintain a regulated electricity supply that is stable at the equipment's optimal operating voltage whether using only the grid as an electricity source or combining the grid with on-site electricity generating sources. Voltage optimisation aims to reduce electricity usage, power demand and cost by reducing supply voltage 'downstream' of the meter. The technology can also improve power quality by reducing harmonic and transient voltages, as well as balance phase voltages[2,3]. A reduction and balancing in electricity supply voltage provides a saving in energy consumption (kWh) and a reduction in maximum demand (kW and kVA) which results in a reduction in electricity bills for the consumer[4]. Other purported benefits include improved power quality, less equipment maintenance, improved equipment life and reduced energy consumption, which all lead to significant cost savings[5].

Voltage optimization technologies have been used by many other industries internationally and locally, however their use has not yet been widespread within the red meat processing sector in Australia. The evidence from application in other related industries is that there is significant scope to reduce energy consumption by optimising the voltage level in facilities in the meat processing industry. Each piece of the equipment at a meat processing plant is designed to operate at a specific current, voltage and frequency to ensure adequate power quality and minimal energy consumption[6]. Therefore, voltage optimisation or compensation reduces energy consumption, but is also beneficial for improving the power factor, reducing harmonics voltage deviations, thereby offering significant potential for reducing costs and carbon emissions for the red meat processing industry.

Techno-economic analysis as part of the AMPC project 2016.1005 "Investigation into Voltage Optimisation Technology for Abattoirs" has shown that for a typical mid-sized (600 head a day) abattoir with a supply voltage of 240 volts and an electricity price of $0.15 a kWh installation of a voltage

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[1] Tang, P. and Jones, M., *Energy Consumption Guide for Small to Medium Red Meat Processing Facilities*, Sydney, NSW: Australian Meat Processor Corporation, 2013.

[2] Tang, P., Horwood, R., and Johns, M., *Literature Review Meat Technology Update*, Sydney, NSW: Australian Meat Processor Corporation, 2013.

[3] Voltage Optimisation: Beyond the hype", Utility Systems Technologies, Inc., 2016. [Online Available]: http://www.ustpower.com/wp-content/uploads/2014/12/UST_White_Paper_Voltage_Optimization_v1dot1.pdf, accessed: 15 Apr 2016.

[4] "What is voltage optimization", Captech. 2016. [Online Available]: http://www.captech.com.au/wp-content/uploads/2015/12/Captech-What-is-Voltage-Optimisation.pdf, accessed 6 Apr 2016.

[5] "Power Controllers - Energy and Earth Resources", *Energyandresources.vic.gov.au*, 2016. [Online Available]: http://www.energyandresources.vic.gov.au/energy/about/legislation-and-regulation/energy-saver-incentive/scheme-documents/review-of-activity-submissions-for-the-energy-saver-incentive-2012/power-controllers, accessed: 20 May 2016.

[6] Brooks, R. and Visser, K., *Saving Electrical Energy and Costs Phase Changing Materials*, Sydney, NSW: Meat & Livestock Australia Limited, 2012.

optimizer will have a payback period of between 3 and 6 years, depending on the supply voltage, type of feeder line and number of VSDs installed. It also found that there are no technical reasons why voltage optimisers should not be installed in red meat abattoirs, and there are in fact many advantages to doing so. Apart from the savings in energy these include less stress on electrical equipment and therefore improved lifetimes with less maintenance, as well as (depending on the technology used) improved power factors and less loss due to harmonics. There is therefore significant benefit from the higher uptake of voltage optimization within the red meat processing industry.

1.2. Why a VO Guide?

1.2.1. Purpose

One of the key reasons for a lack of investment in energy efficiency initiatives (including voltage optimsers) by industry, despite the evident potential financial savings, is a lack of knowledge about the technology and guidance on how to assess its suitability and subsequently implement it at sites. This Voltage Optimisation Guide has been prepared to provide the knowledge about voltage optimisers and how to implement them specifically for the red meat industry. It will provide relevant people within the red meat processing industry with information to:

- Understand the basics of voltage optimization.
- Understand the potential benefits and impacts of voltage optimization for red meat processing facilities; and
- Provide a clear and simple decision-making framework to consider the applicability of voltage optimisation for a site.

The process of understanding and implementing voltage optimisation can be complex. By providing some practical examples, case studies and responses to common questions, the Guide can be used to provide direction and justification for further investment (e.g. performing a detailed feasibility assessment).

In most cases detailed investigations will be required to be performed by suitably qualified specialists (either within, or outside of the site), or systems suppliers. These investigations can typically incur time, cost and effort and so it is important to be confident in decision-making that voltage optimisation is a good fit for the site prior to embarking on a detailed feasibility assessment. This guide is designed to assist to do this initial analysis.

1.2.2. How to use this Guide?

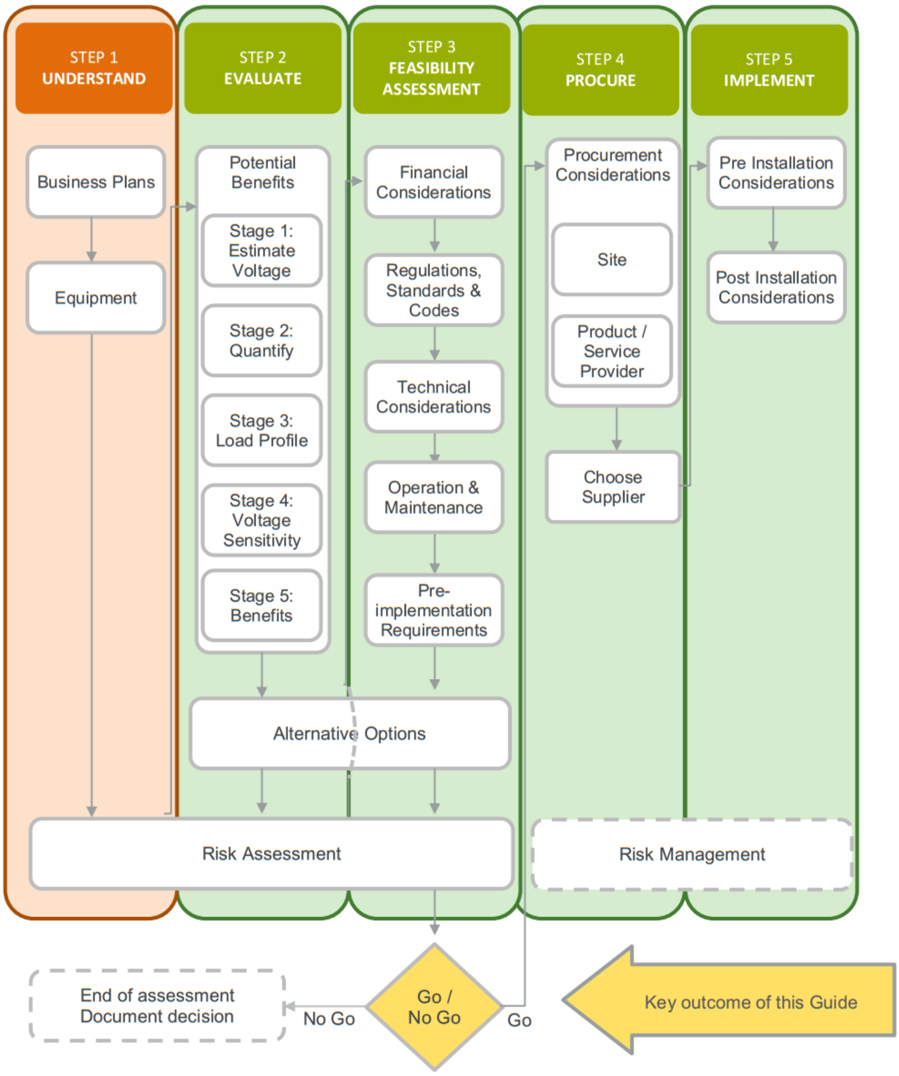
The Guide has been separated into two sections; a background to voltage optimisation and a detailed decision-making framework/guide.

Section 1 covers general voltage management concepts that are required to make an informed decision regarding voltage optimisation. The section also includes a voltage sensitivity checklist that can help to determine if your site's equipment is suited for voltage optimisation. Additionally, the Guide outlines alternatives to voltage optimisation that may be considered for your site. Overall, this section will provide you with information regarding three key focus areas:

Section focus areas

WHAT IS VOLTAGE?	HOW CAN VOLTAGE BE MANAGED?	WHAT IS VOLTAGE OPTIMISATION?

Section 2 details a step-by-step decision-making process for a voltage optimisation investment opportunity. The process will facilitate site staff in deciding what the benefits and impacts of voltage optimisation may be at their site. The flow chart below outlines the active process that site staff should undertake in determining the suitability of voltage optimisation at their site.



1.3. Acknowledgement:

This voltage optimisation guide has been prepared by tailoring material originally developed for the New South Wales Office of Environment and Heritage (OE&H), "i am your guide to voltage optimisation: is it right for you?"[7] considering to the red meat processing industry.

[7] The NSW OE&H voltage optimisation guide is available from http://www.environment.nsw.gov.au/resources/business/160226-voltage-optimisation-guide.pdf.

SECTION 1 – BACKGROUND

2. Voltage Optimisation

2.1. The Supply of Electricity

Power stations generate electricity which is transformed to high voltage- 6,600 volts to 33,000 volts (or, 6.6kV to 33kV). To enable the transmission of electricity over long distances, transformers increase voltage to 66kV, 110kV, 132kV, 220kV, 275kV or 500kV. High voltage transmission is often required to reduce energy losses (e.g. associated with wire heating over long distances).

Voltage is then subsequently reduced to levels suitable for distribution (e.g. ~240V single-phase and 415 V in three-phase) to operate electrical equipment and appliances. Larger sites (e.g. industrial sites, large manufacturers) may require high voltages (e.g. 6.6kV, 11kV, 22kV, 33kV). Electricity network operators supply electricity at suitable voltage for all end-users, including 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 utilised 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. When electricity reaches a site, Australian Standards stipulate that the voltage drop allowable in an electric system (e.g. within a site) should not exceed 5%.

Some electrical equipment designers configure their equipment to operate within the recommended voltage rating of 240V (+10% to -6%). More recently manufacturers are configuring their equipment to operate with a nominal voltage of 230V.

Voltage Supply Standards in Australia

Standards Australia developed AS 60038 to provide guidance regarding voltage levels for electrical supply systems. AS 60038 recommends voltage should be supplied at 230V (+10% to -6%), therefore providing an allowable voltage supply range between 253V and 216V. Voltage drop within a site should not exceed 5%

These standards influence the way an electrical system or equipment is design (i.e. the electrical equipment designer can choose what is the optimum voltage level to operate an electrical appliance).

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

Common characteristics associated with changes in voltage levels:

Voltage Level		Characteristics / Issues
253V and more	OVER VOLTAGE Over voltage is excess voltage. It is commonly	• Electrical equipment overheating. • Electrical circuit failure – tripping of protection system or insulation failure. • Reduced equipment operating life.

	characterised by power swells or surges.	• Consequential impacts such as production and operation issues.
~230V	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.
216V and less	UNDER VOLTAGE Under voltage 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 AC motors. • Electrical circuit failure – overheating. • Reduced equipment operating life. • Consequential impacts such as production and operation issues.

The characteristics/issues described above depend on the severity and duration of the over or under voltage event.

For certain loads, a reduction in voltage will reduce the overall power consumed. This in turn may provide energy savings. A common example of trying to reduce power consumption by changing voltage is in equipment with a linear resistive load such as incandescent lamps. It should be noted that some equipment's power consumption may be less impacted by changes in voltage. This equipment is considered to be non-sensitive to normal fluctuations in voltage supply.

2.2. Typical Abattoir Electricity Consumption

In reviewing the application of voltage optimisation technology to the Australian red meat processing industry, it is important to understand the typical energy consumption of an abattoir and types of electricity using equipment. Most meat processing facilities can be categorized according to the activities performed at the facility and these can include[1]:

a) Slaughter only or Boning only;
b) Slaughter and Boning;
c) Processing; or,
d) Rendering.

The main energy consuming equipment found at abattoirs include refrigeration plant, steam and hot water generating equipment, pumps, lighting loads and air compressors[1].

The electrical distribution (via transformers and or switch boards) at small to medium abattoirs with rendering can be divided into the following areas (with rough percentage of consumption)[8]:

- Refrigeration - 50 %;
- General production (kill floor, boning room) – 23%;
- By-products/rendering – 15%;

[8] Sam Hain, David Clapham and Robert Eley, "Monbeef Energy Report. Part 1 – Electrical Audit", 25th August 2009.

- Office, workshops, amenities and auxiliary services (e.g. boilers etc.) – 5%;
- Water pumps (5%);
- Dams (agitators and pumps etc.) - 2%.

On a day-to-day basis, typical electrical load profiles for a meat processing facility in Australia reveal that electric power consumption is the highest during boning and the initial stages of carcass cooling which occurs from 05:00 to 14:30, Monday to Friday.

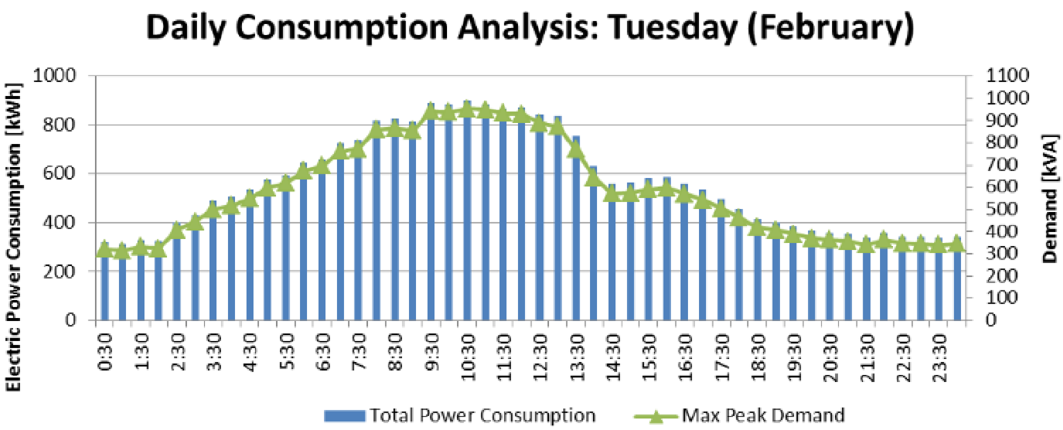


Figure 1 – Typical weekday electricity consumption profile for an Australian meat processing facility[1].

As compared to a typical weekday, which has distinct peak throughout the day, the typical weekend electricity consumption is relatively constant throughout the day.

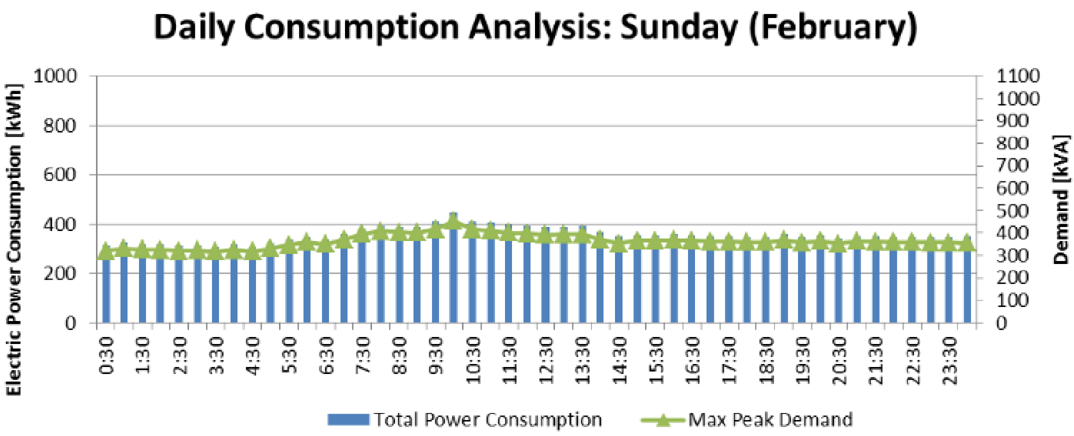


Figure 2 – Typical weekend electricity consumption profile for an Australian meat processing facility[1].

From analyses undertaken in the Domestic Processors Energy Efficiency Program[1], electricity consumption in Australian abattoirs increases during summer due to additional cooling and refrigeration requirements.

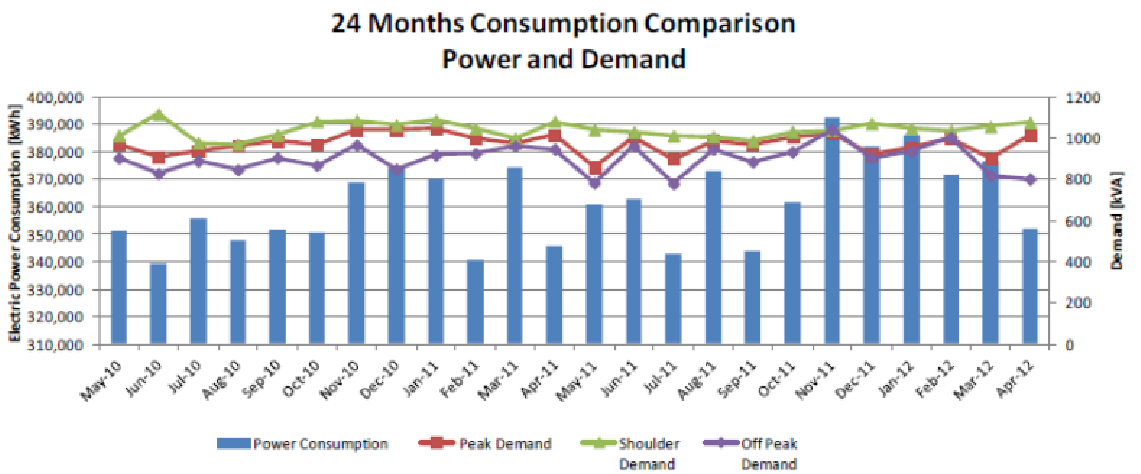


Figure 3 – Twenty four month electricity consumption profile for an Australian meat processing facility[1].

What can be gleaned from typical energy consumption quantities, proportions and usage patterns in Australian red meat processing facilities is that there is potential scope for voltage optimisation during periods of high electricity demand regardless of whether the site has rendering or non-rendering activities.

2.3. Equipment Voltage Sensitivity

Key Points:

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

All electrical devices have a power rating measured in watts or volts-amperes. Power rating is the optimum power required for the equipment to operate effectively. Electrical equipment manufacturers design equipment to function at a voltage range (for example within a range of 220V to 240V) to enable their equipment to operate effectively.

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

- The type of equipment (e.g. motors, pumps, lighting, information and communications technology) and its size.
- The power rating of each equipment.
- The operation of the equipment (e.g. continuous vs 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); and
- The equipment design, amongst others.

Based on the relationship between voltage and power consumption, the voltage sensitivity of equipment can be broadly categorised into the following:

Equipment Sensitivity	Reasoning	Why Important?
VOLTAGE SENSITIVE	Power consumption and/or output of an appliance varies depending on the voltage supplied.	Understanding how voltage sensitive equipment is will determine the potential benefits of voltage optimisation.
VOLTAGE NON-SENSITIVE	Appliances designed to have a fixed power consumption and output, irrespective of the voltage supplied.	

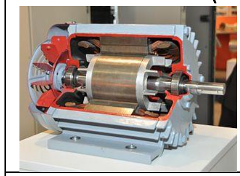
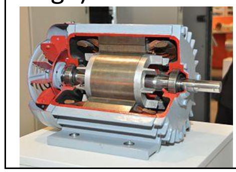
2.3.1. Voltage Sensitive Equipment

Examples of common electrical equipment and their associated voltage sensitivity are provided below. This checklist can be used to determine whether equipment is sensitive to voltage or not. Whilst this checklist is intended to provide guidance on the voltage sensitivity of common electrical equipment, it is recommended to check with an electrical engineer or energy specialist (e.g. electricians, suppliers, consultants) about the voltage sensitivity of particular equipment at the site if available.

EQUIPMENT TYPE	VOLTAGE SENSITIVITY		REASONING
	Sensitive	*Non-Sensitive*	
LIGHTING Lighting can be a significant electricity consumption source. Importantly: • The light output of a voltage sensitive lamp (i.e. the strength of the light emitted) is impacted by the voltage level. • The life expectancy of the lights may vary if the voltage is increased or decreased.			
			Incandescent lamps are no longer available to purchase for commercial applications (they may be available for decorative purposes) in Australia. Most were designed to operate on a 240V supply and are voltage sensitive. A change in voltage will impact the output of light.

EQUIPMENT TYPE	VOLTAGE SENSITIVITY		REASONING
	Sensitive	*Non-Sensitive*	
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) 			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) 			An electronic ballast regulates voltage and delivers a constant output, hence fluorescent lamps with electronic ballasts are voltage non-sensitive.

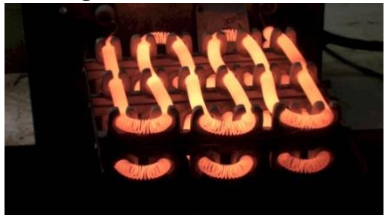
EQUIPMENT TYPE	VOLTAGE SENSITIVITY		REASONING
	Sensitive	*Non-Sensitive*	
Fluorescent lamps (high-frequency) 			High-frequency fluorescent lamps are either passively or actively electronically controlled. Active controlled fluorescent lamps utilise integrated circuitry at the front end of the lamp, whereas passive 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 (HIDL) (inductive ballast) 			Discharge lamps involve current being passed through a gas resulting in the production of light. Generally, these lamps use conventional ballasts. Examples of HIDLs include: Mercury vapour lamps; Sodium vapour lamps and 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 (HIDL) (electronic ballast) 			Similar to other electronic controlled lamps, HIDLs with electronic ballast are not impacted by normal voltage variations, therefore making these lamps non-sensitive. The electronic ballast regulates voltage and delivers a constant output.
Induction Lamps 			The mercury in a typical induction lamp is stimulated into producing light using a magnetic field. The lamps are operated by electronic control gear and are classified as non-sensitive to voltage.
Light Emitting Diodes (LED) 			Light Emitting Diodes (LED) pass electricity through a semiconductor which produces photons (a basic unit of light). LEDs are electronically controlled and hence are non-sensitive to normal voltage variations.

<table>
<tr><th rowspan="2">EQUIPMENT TYPE</th><th colspan="2">VOLTAGE SENSITIVITY</th><th rowspan="2">REASONING</th></tr>
<tr><th>Sensitive</th><th>Non-Sensitive</th></tr>
<tr><td colspan="4">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 a relation between voltage and electrical current (measured in amperes).
Over voltage
An increase in voltage may draw excess electrical current in an attempt to increase the motor’s magnetic field. Therefore, over voltage may cause overheating and a decrease in the life expectancy of the motor.
Under Voltage
When voltage is decreased, the electrical current increase in order to provide the power required by the motor. Impacts of under voltage may include:
Decrease in torque capability, which requires the motor to work harder to achieve the required output;
Overheating may occur, which may damage the motor; and
Potential decrease in the life expectancy of the motor.</td></tr>
<tr><td>Motors – linear (fixed) speed (small)
</td><td>✅</td><td></td><td>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.</td></tr>
<tr><td>Motors – linear (fixed) speed (medium to large)
</td><td>✅</td><td></td><td>Medium to large size 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 small motors.</td></tr>
</table>

EQUIPMENT TYPE	VOLTAGE SENSITIVITY		REASONING
	Sensitive	*Non-Sensitive*	
Motors – permanent magnet (PM) 			Permanent Magnet (PM) motors use magnets to produce the rotating force rather than electromagnets. 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.
Motors – variable speed (controlled) 	?		A speed control can be used on a motor with a variable load or partial load. These controls run the motors at reduced speeds using a variable-voltage, variable frequency drive (VVVF). The VVVF are also commonly referred to as a variable frequency drive (VFD) or variable speed drives (VSD). As the control device regulates the voltage supplied to the motor, these motors are less sensitive (although still somewhat sensitive) to voltage variations in the mains feed.

EQUIPMENT TYPE	VOLTAGE SENSITIVITY		REASONING
	Sensitive	*Non-Sensitive*	
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 system.			
Refrigeration (uncontrolled) 	✓		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) 	?		Electronically controlled refrigeration units (e.g. refrigeration systems with variable speed devices) may be considered as somewhat voltage sensitive since: • the speed of the motor is being adjusted to suit the requirements of the refrigeration system; and • some variable speed devices are somewhat sensitive.

EQUIPMENT TYPE	VOLTAGE SENSITIVITY		REASONING
	Sensitive	*Non-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 and are normally complex systems.			
HVAC (flow uncontrolled) 	✓		Some HVAC systems are reliant on the mains voltage supply. In those cases, an uncontrolled HVAC system can be sensitive to voltage variations at a light load.

EQUIPMENT TYPE	VOLTAGE SENSITIVITY		REASONING
	Sensitive	*Non-Sensitive*	
HVAC (inverter) 			Some HVAC systems use inverters to control the speed of motors to have a constant load (i.e. using a VVVF drive). Similar to other technologies that have electronic control devices, a HVAC system that uses an inverter is generally non-sensitive to normal voltage supply changes.
Heating – coil / resistance 			Heating is normally controlled by a thermostat (the thermostat controls how long a heating device operates). 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. Consideration should be made in cases where a heating coil operate continuously (i.e. the coil is heated 24/7), in such cases, the equipment will be voltage sensitive.

EQUIPMENT TYPE	VOLTAGE SENSITIVITY		REASONING
	Sensitive	*Non-Sensitive*	
OTHER COMMON EQUIPMENT There are a variety of other common electrical equipment types that are normally non-sensitive to voltage variations.			
Information technology (IT) equipment 			Most Information Technology (IT) electronic equipment operates at a fixed voltage level, independent from the supply. Battery-powered equipment normally have a transformer to convert the mains electricity supply voltage (e.g. 230V) to a lower voltage (e.g. 15V). IT equipment is therefore generally considered voltage non-sensitive.

EQUIPMENT TYPE	VOLTAGE SENSITIVITY		REASONING
	Sensitive	*Non-Sensitive*	
Uninterruptible Power Supply (UPS) 			Uninterruptible Power Supply (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 using inverters (surge protection) 			Equipment using an inverter is generally non-sensitive to normal voltage variations. The voltage output from the inverter is designed to be a constant output. More complex inverters may allow voltage output levels to be selected to suit the specifications of the electrical device.

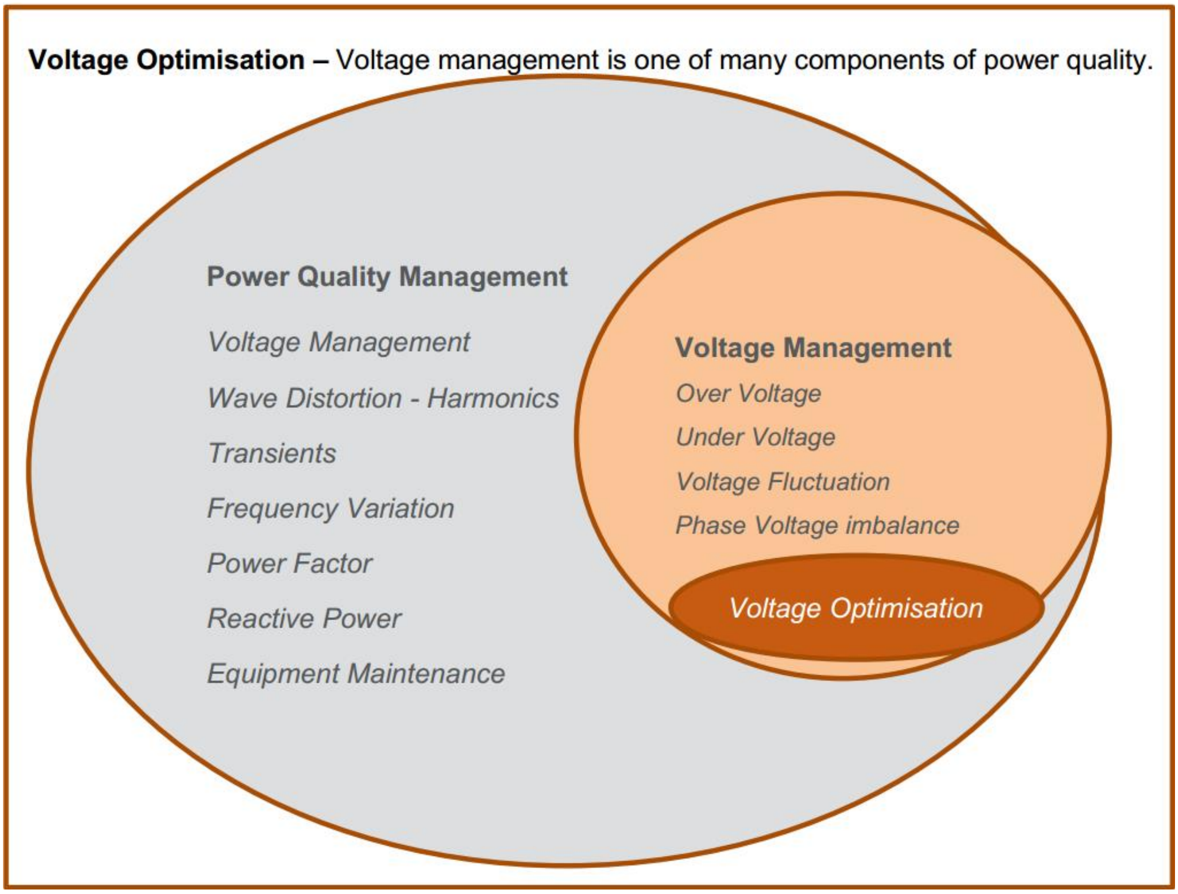
2.3.2. How Can Voltage Be Managed?

Key Points:

- *Voltage can be managed in different ways – it can be stabilised, regulated, reduced or optimised.*
- *There are alternatives to voltage optimisation.*

For the purposes of this Guide, voltage optimisation is considered as a component of voltage management. Depending on how voltage may impact the operations, productivity and performance of an asset, voltage management may include:

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



2.4. Introducing Voltage Optimisation

> Key Points:
>
> - *There are a number of voltage optimisation technologies available in Australia.*
> - *Voltage optimisation should ensure an appropriate level of voltage is supplied to operate equipment.*
> - *In a site which is supplied with a higher voltage than required, voltage optimisation technology may assist in reducing energy consumption, maximum demand and costs.*
> - *Understand your electrical equipment before implementing voltage optimisation.*

A key reason for the original development of voltage optimisation technology was to minimise damage to equipment caused by operating at voltage levels above or below equipment power ratings. Therefore, as well as reducing energy consumption voltage optimisation can also assist with reducing maintenance requirements and increasing the operating life of some equipment.

Voltage optimisation technology aims to adjust the supply voltage levels (i.e. supplied at a range between 253V and 216V) to a specific voltage bandwidth (e.g. 230 V ±1% or 220V ±1%). Section 2.4.1 highlights common types of voltage optimisation units and how they work.

Some of the potential benefits of voltage optimisation as detailed in publicly available literature (e.g. voltage optimisation unit manufactures and suppliers) are:

- Supply the optimum voltage level to equipment;
- Reduce the electricity consumption of certain voltage sensitive equipment and consequently reduce indirect greenhouse gas (GHG) emissions;
- Overall increase in the lifetime of electrical equipment;
- Potentially reduce maintenance frequency, effort and costs; and
- Improve overall power quality (e.g. reduction in voltage feedback, reduced overvoltage, lower levels of harmonics and prevention of transients) – this depends on the type of voltage optimisation technology implemented.

2.4.1. Types of Voltage Optimisation Equipment

The following table outlines some of the common voltage optimisation units.

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 variations as the supply) at a lower voltage than the supply.	• Generally cheaper than dynamic systems. • Small sized unit. • Ideal for a site where the 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).

	These units use magnetic couplings that transmit an electric load and use a secondary winding that applies an induced opposing voltage. They do not reactively adjust to voltage supply levels.		
Dynamic System – Voltage Optimisers	Voltage optimisers aim to dynamically adjust voltage levels within a specific range. This output is aimed to supply 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 to 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 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. • Does not compensate for voltage drops in the supply (some voltage optimisers have protection against voltage drop). • Depending on the unit, the voltage optimisers are generally larger than voltage regulators.
Dynamic System – Boosted Voltage Optimisers	Other 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 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. 216V).

2.5. Alternative Options to Manage Voltage

There are a number of alternative options to manage voltage. These include:

- If under or over voltage has been identified as a potential issue to your site, consideration should be given to, for example:
    - A detailed power quality assessment.
    - Load balancing.
    - The installation of power conditioning.
    - The installation of equipment that have wider voltage tolerances; and
    - The installation of under or over voltage protection equipment.
- Modify voltage from the incoming transformer (high-voltage and medium-voltage sites with onsite utility transformer).
- Install a small voltage optimisation unit to service specific parts of your site.
- Replace voltage sensitive equipment; and
- What about Power Factor Correction (PFC)?

Section 2 of this Guide provides further information on how to assess if voltage optimisation is a suitable opportunity for a site.

2.6. Electricity Profile in Abattoirs and Voltage Optimisation

Figures 4 and 5 show example voltage and current profiles for two typical small to medium red meat processing abattoirs in Australia over 3 weekdays and 1 week respectively. The abattoir in Figure 4 (showing "whole of site") has a significant opportunity for the use of dynamic system voltage optimisation (reduction, regulation) as the average voltage is relatively stable at ~240 V, with the voltage predominantly staying within 5% of the average value.

Figure 4. ***Current and voltage profiles over a three-day period for an example red meat abattoir.***

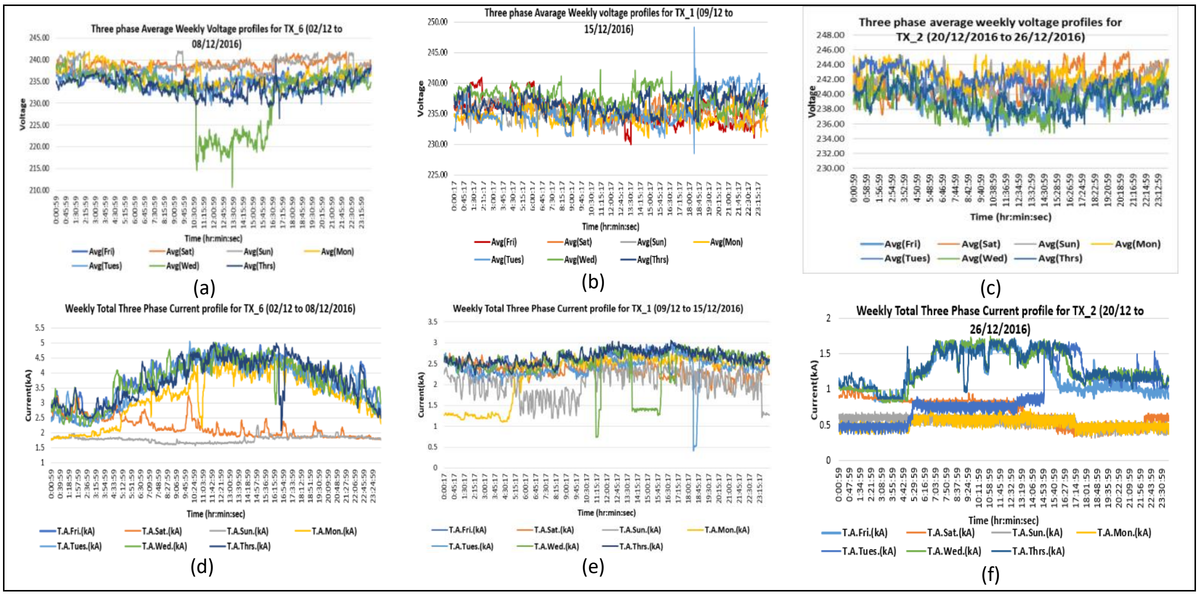


Figure 5. Weekly average three -phase voltage profiles for three transformers in a typical abattoir.

This abattoir has a lower average voltage, with numerous voltage drops below the recommended minimum voltage of 220V. As well as reducing efficiency, these under voltages, particularly if they are rapid, can cause damage to the motors, increasing maintenance requirements and decreasing motor life. Depending on the economics of the specific situation an abattoir such as this could benefit from dynamic system boosted voltage optimisation (regulation, optimization) where the voltage can be dynamically boosted as well as reduced.

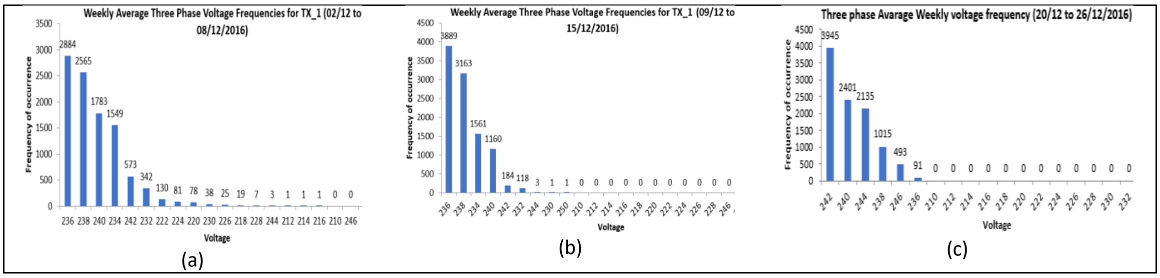
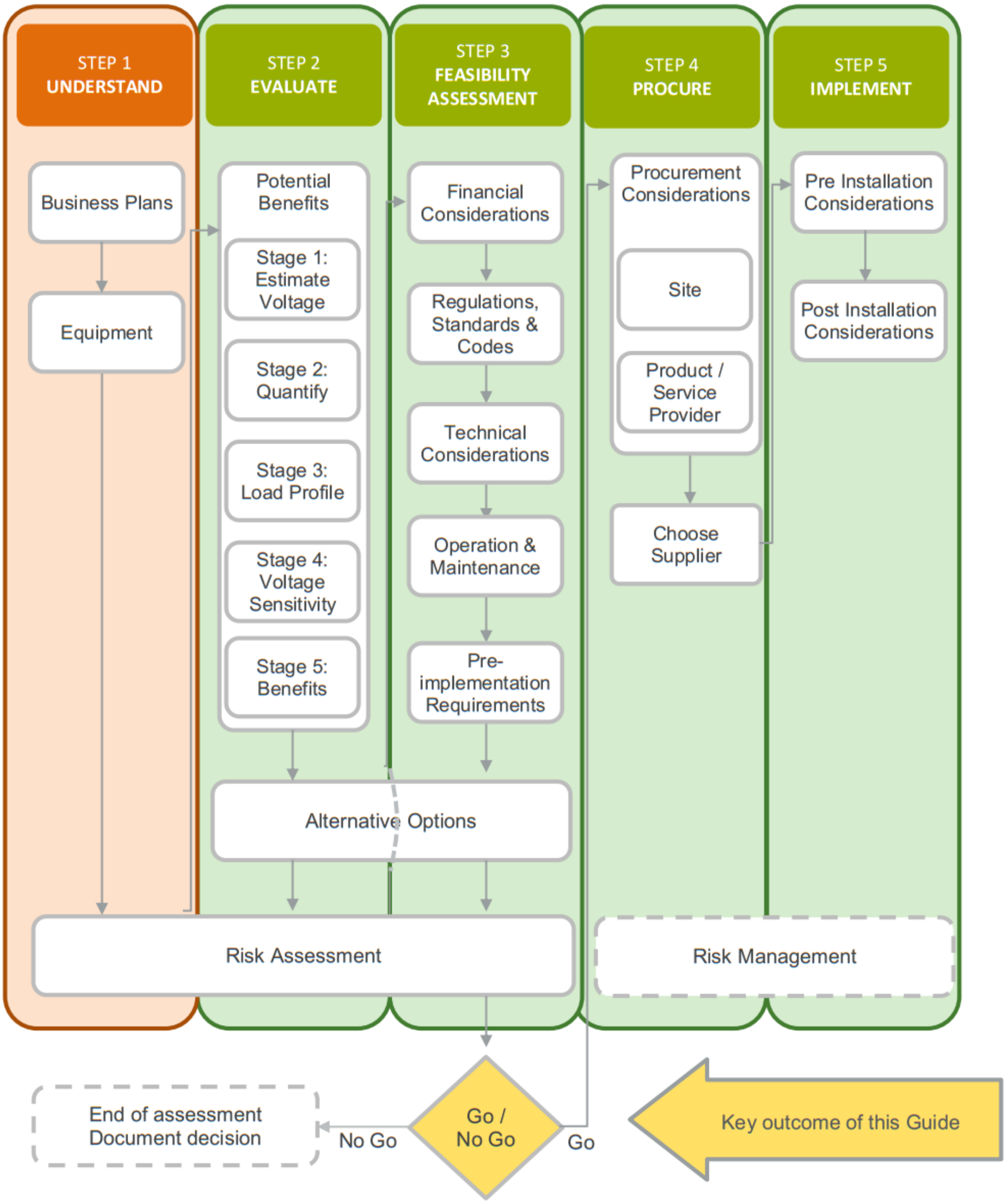


Figure 6. Weekly total (across all three phases) voltage frequency histogram for transformers TX_6 (a), TX_1 (b) and TX_2 (c).

The decision making guide in the next section provides guidance for red meat processing facilities such as these on how to decide whether voltage optimization is suitable for them, and the steps required to then progress to installation.

SECTION 2 – DECISION MAKING GUIDE



The New South Wales Office of Environment and Heritage (OE&H) have published a detailed voltage optimization guide for business, "i am your guide to voltage optimisation: is it right for you?" which is available at http://www.environment.nsw.gov.au/resources/business/160226-voltage-optimisation-guide.pdf.

Readers of this guide are encouraged to refer to the NSW OE&H guide for more details and a number of helpful templates for voltage optimisation assessments.

3. STEP 1 - UNDERSTAND

Step 1 of the Guide aims to guide you through preliminary considerations to understand the suitability of voltage optimization for your processing site. At the completion of this step you will be able to make a confident decision whether to allocate time and resources to further evaluate the technology.

TIP

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

- *Key stakeholders*
- *Electricity consuming equipment on site and its voltage sensitivity*
- *Issues, benefits and sensibility of the investment; and*
- *Business needs, drivers and plans.*

3.1. Consider Your Business Plans

Considering your business/site plans will help you to understand the appropriateness of voltage optimisation. As part of this process, you should consider the following elements:

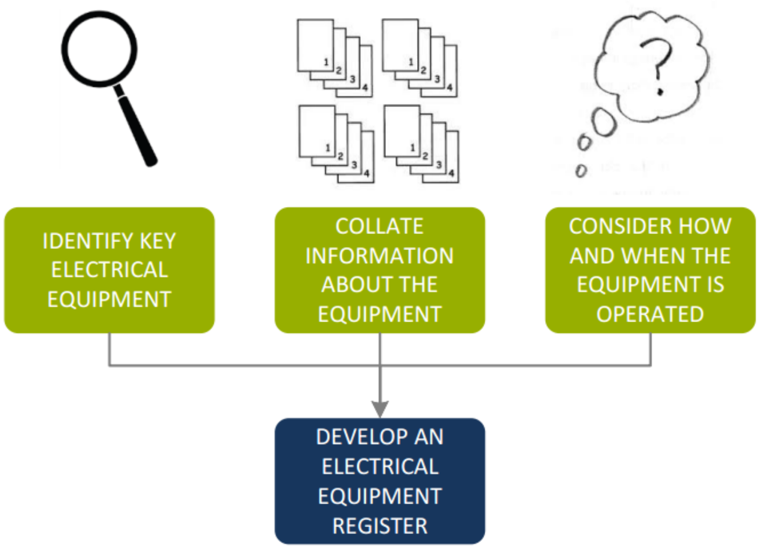
Element	Key Considerations
Business drivers	• Business drivers behind considering voltage optimisation (e.g. costs reductions, energy savings). • Financial expectations or hurdles (e.g. payback period, Return on Investment).
Site plans / strategies	• The current situation of your site (e.g. owned or leased premises). • The medium and long-term strategy (e.g. life of business). • Planned activities (e.g. upgrades, expansions, developments, decommissioning). • Foreseen 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.

General operations and maintenance considerations	• Current maintenance and replacement frequency (including associated costs). • Known issues associated with your site's electrical infrastructure.

3.2. Understand Your Electrical Equipment

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

It is recommended you develop a register of key electrical equipment. This should include the following simple steps:



> **CAUTION**
>
> *Only safe visual inspections should be performed in accordance with legislation and company protocols.*
> *It is recommended certified personnel develop the electrical equipment register.*

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, etc.)
  - Power ratings (kW)
  - Voltage ratings (V); and
  - Equipment utilisation rates (e.g. the percentage of time the equipment operates over a given period of time).
- Voltage sensitivity (refer to sections 2.3.1 for the voltage sensitivity checklist and 3.2.1 for guidance).
- Other information such as:
  - The role of the equipment (e.g. primary or standby pump, general lighting, security lighting, uninterruptible power supply).
  - The equipment replacement or upgrade dates (e.g. maintenance plan).
  - Criticality of the equipment; and
  - Unique characteristics of the equipment (e.g. variations in how it operates under

different production scenarios, seasonality requirements, etc.).

> **TIP**
>
> - A register of electrical equipment may already exist within your business.
> - If a register exists, check whether it is accurate, complete and up to date.
> - If a register does not exist, a suitable person can collate information from the equipment's nameplate or electrical line diagrams.
> - Ensure all safety requirements are followed when inspecting equipment. Due to the location of certain equipment, it may not be practical to collate the nameplate information. The importance of missing information needs to be considered against how much electricity the equipment consumes and its voltage dependency.
> - For guidance, an equipment register template is in Toolkit 2 of the NSW OE&H voltage optimization guide.

3.2.1. Understand your Equipment's Voltage Sensitivity

Following the identification of the electrical equipment at your site, you should perform a high-level voltage sensitivity assessment. Categories your equipment into either voltage sensitive or voltage non-sensitive. If a large number of electrical devices or key equipment are voltage sensitive, a decision may be made to further evaluate the appropriateness and potential benefits of implementing voltage optimisation. On the other hand, where key equipment or a large proportion of the equipment is non-sensitive a decision may be made not to proceed with further evaluation.

A template for determining voltage sensitivity is given in the Toolkit 1 section of the NSW OE&H voltage optimization guide.

> 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. electrical engineer, energy consultant) to provide support and guide you through the process.

3.2.2. Understand your Electricity Consumption

To determine the potential savings associated with the installation of voltage optimisation, you should understand your facility's electricity consumption profile. Electricity invoices or metered data may provide sufficient information to answer the following questions:

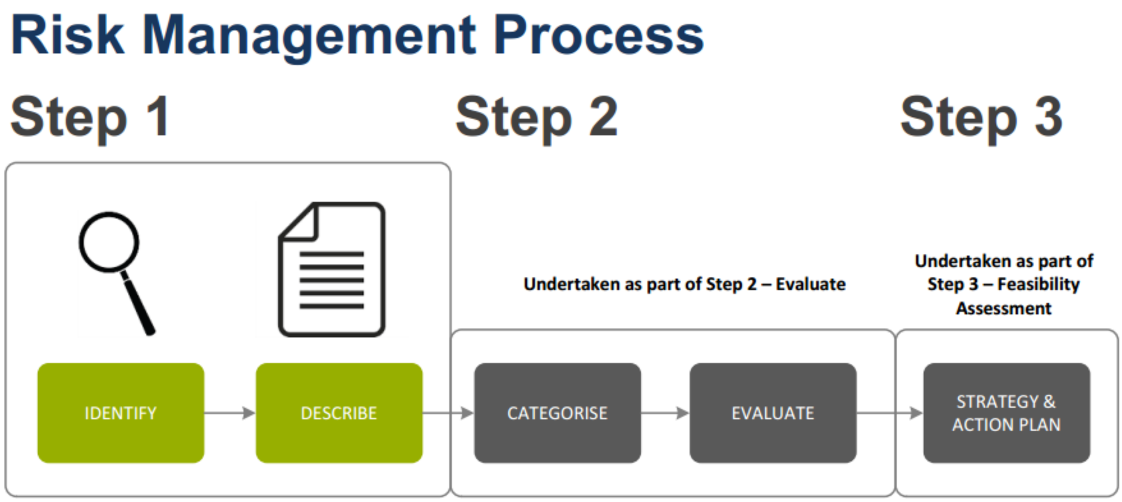
- How much electricity does your site consume (e.g. kWh/annum)?
- How much does your electricity cost (i.e. AUD$/kWh and AUD$/kVA or AUD$/kW)?
- What is your site's demand profile (i.e. maximum demand in kVA or kW)?
- What is your site load/energy balance (i.e. % used by different systems such as lighting,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

Example load profiles of typical medium sized abattoirs are shown in section 2.6.

3.3. Risk Assessment: Understand Potential Risks

Understanding the potential issues and risks associated with voltage optimisation is important to establish mitigation measures. In line with the company's normal procedures and processes the risks should be reassessed at every step of the process (i.e. throughout the evaluation (Step 2) and feasibility (Step 3)) to ensure appropriate mitigation.

The following process should be considered to determine and manage potential risks associated with assessing the benefits of, and installing a voltage optimizer at a red meat processing facility:



Appendix A provides examples of common risks and issues that could be encountered when considering voltage optimization.

> TIP
>
> - The early identification of risks should minimise their impact on costs and timing.
> - Involve a variety of stakeholders in the risk identification process.
> - Refer to Appendix A for reference to common issues and risks that should be considered when assessing the suitability of voltage optimisation.

3.4. Case Study – Understand

> A RED MEAT PROCESSING COMPANY CONSIDERS VOLTAGE OPTIMISATION
>
> Overview of the Project
>
> A red meat processing company performed several energy audits of its abattoir sites to identify opportunities to save energy and operational costs. An opportunity was identified to implement voltage optimisation with reported savings of up to 7% of a site's total electricity consumption.
>
> The company 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 of equipment on site (i.e. the site's voltage sensitivity).
>
> As the company has critical infrastructure on its sites (such as freezer and refrigeration equipment), they decided to better understand their equipment and their loads prior to implementing a new technology.

Additionally, the company realised that in order to make an informed investment decision, they required to understand:

- The equipment history (e.g. the date when the freezer, refrigeration and other equipment were installed and if there had any major retrofits); and
- The medium to long-term plans for the site and the equipment (e.g. refrigeration system retrofitting plans, planned expansions, lease plans, etc.)

Activities undertaken

To understand the equipment and their equipment loads, the business:

- Developed a detailed asset register.
- Documented the history of the equipment (e.g. commissioning, major retrofits, etc.).
- Considered the medium to long-term plans of the sites; and
- Engaged a consultant to examine supplier proposals regarding voltage optimisation.

Results

Key findings from undertaking these activities included:

- Several sites used a mix of voltage sensitive and voltage non-sensitive equipment.
- Some of the sites were subject to major retrofits plans that included freezer and refrigeration system upgrades.
- There was a need to upgrade some site's electricity meters to monitor real time voltage, or have one off measurements done, and determine the need for voltage optimisation.
- There are different voltage management technologies, specifically:
    - Fixed voltage regulators which reduce the voltage by a certain percentage; and
    - Dynamic voltage regulators which step down the voltage to a set output (e.g. 220V ±1%).

Key success factors:

- Ensuring a thorough understanding of the site and equipment.
- Developing an accurate and complete asset register; and
- Considering the medium to long-term plans for each site.

4. STEP 2 - EVALUATE

To evaluate the potential benefits of voltage optimisation, the following step-by-step staged approach is recommended to be followed. An example of a site owner undertaking each of the stages has been provided to highlight how these can be undertaken in a practical manner.

4.1. Stage 1 – Determine Voltage Over-Supply and Voltage Tolerances

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

- An accurate and complete equipment register; and
- An electrical equipment load profile.

To determine the potential voltage over-supply to your site, you will need to following steps:

<table>
<tr><td colspan="2">Estimate your site's average supply voltage</td></tr>
<tr><td>
</td><td>Determining your site's average supply voltage can be performed by estimate, determined by your electricity retailer or direct measurement. You should consider the pros and cons of each option, for example:
• estimating the voltage supplied to site might be inaccurate;
• your electricity retailer may not be able to provide you with the information (i.e. only certain sites have the metering capabilities); and
• direct measurement is more accurate and can be performed at various points in the electrical system, however it may require long time and can be costly.
These options are explored in further detail below.</td></tr>
<tr><td colspan="2">Electricity Retailer Voltage Supplied

For some sites, the electricity retailer may retrieve information about the voltage supplied to the site for each electricity meter installed on site. The electricity bill should detail a National Meter Identifier (NMI) for any incoming meters installed at your site. The NMI is your site's unique meter identifier and will be required when requesting the electricity consumption information from the retailer.

TIP

Request the supplied voltage to your site from your electricity retailer.</td></tr>
</table>

Estimate your site's average supply voltage

Direct Measurement

Direct measurement (e.g. using power quality meters/analysers, meters, a multimeter or a voltmeter) is the preferred method of measurement as it will provide accurate data about your site supply voltage levels. However, consideration should be given to potential costs, time and need for specialists to undertake the measurement.

When performing direct measurement, consider:

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

Depending on the level of accuracy required by your business, detailed measurement and monitoring can be undertaken as part of Step 3 – Feasibility Assessment.

Estimate

As discussed in Section 1, nominal voltage supply levels range between 216V to 253V. You can select a value within this range (e.g. 245V) or contact your electricity retailer for information.

WORKING EXAMPLE

A red meat processing site 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 undertake direct measurement due to time and resource limitations. Consequently, the owner estimated that the site was supplied electricity at 245V. The estimated voltage supply value was carried throughout the evaluation process to estimate the benefits of voltage optimisation.

TIP

- *Due to the dangers of direct measurement, all direct measurements must be undertaken safely and be performed by an accredited electrical specialist.*
- *Some sites may meter voltage through a Building Management System (BMS) or equivalent, potentially reducing or eliminating the need for separate logging.*

Estimate average voltage losses within your site	
Estimate 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%, normally the voltage drop within an electric circuit is between ±1 or 2%). As part of the evaluation stage and in line with the above-mentioned standards, a 5% voltage drop can be considered for evaluation purposes, therefore representing the maximum allowable voltage drop within the circuit. For a more accurate estimate of the losses, the following methods can determine the voltage drop within an electric circuit: • Calculation - estimate the losses based on the distance and caliber of the wiring within the system; and • Direct measurement - measurement can be performed within an electric circuit where the voltage is at its lowest point (i.e. the point of consumption furthest away from the supply). These calculations and measurements can also be performed in Step 3 – Feasibility Assessment.

WORKING EXAMPLE

As a conservative measure, the site owner considered a 5% voltage drop within their site's electric circuit. The site will consider this voltage drop when specifying the minimum allowable supply voltage for the site.

Estimate minimum voltage allowable for your equipment	
Identify 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, understanding what the minimum voltage levels of your equipment will establish the voltage supply baseline. It should be noted that voltage requirements vary between electrical equipment. For example, sites that have aging equipment may have equipment designed for 240V (rather than 230V). The minimum allowable supply voltage should also consider voltage losses (e.g. 5%) in the electrical system. For example, if 220V has been determined as the minimum allowable voltage for certain equipment, the site should be supplied with ~232V (i.e. 232V – 5% = 220.4V).

WORKING EXAMPLE

Based on the equipment information collected as part of Step 1 - Understand, the site owner identified that most of the electrical equipment was rated for 230V and could operate at 220V.

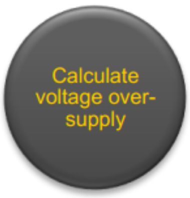
However, the freezer and refrigeration systems were the original from the 1990's and are planned for replacement later in the year. The refrigeration system has a rating of 240V and consumes approximately 50% of the site's electricity usage. Therefore, the minimum allowable voltage was strongly influenced by the refrigeration system leading to a required voltage level of 240V.

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

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

4.2. Stage 2 – Quantify Energy Consumption and Costs

Calculate the potential voltage oversupplied at your site



To estimate the potential over-voltage for your site, the following steps should be followed:

a) Add the potential voltage losses within the electrical circuit (e.g. 5%) to the minimum allowable voltage for the equipment (e.g. 220V). This value represents the lowest potential voltage to be supplied to your site (i.e. 232V);

b) Subtract the supply voltage level with the potential supply voltage level (e.g. 245V – 232V = 13V).

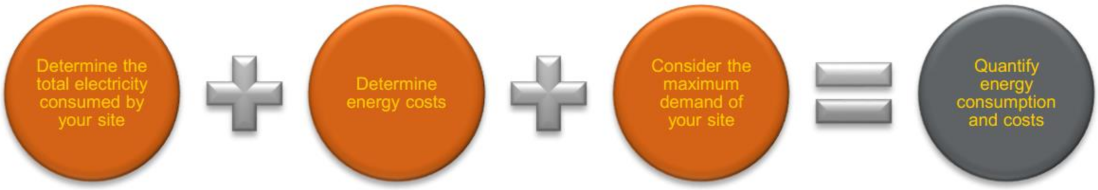
WORKING EXAMPLE

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

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

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

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



To complete this stage, you will require invoices detailing electricity consumption (kWh) and cost per kWh. These activities are described in detail below.

Determine the total electricity consumed by your site	
	You can determine the total electricity consumed by your site (in kWh) by utilising information obtained in *Step 1: Understand*. Key considerations when undertaking 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.

TIP

- *Consider at least 12 months of electricity consumption data.*
- *Highlight any increase/decrease in electricity consumption and probably causes (e.g. weather influences i.e. winter vs summer or site operations that might have caused these fluctuations.*

Interval data

Fifteen or 30-minute interval electricity consumption data may be made available from electricity retailers for each electricity meter installed on site. Your NMI will be required when requesting the electricity consumption information from the retailer.

Determine your energy costs	
	Electricity prices are comprised of a variety of charges (e.g. electricity charges, network charges, demand charges, etc.). This information is detailed in your electricity invoice. Consider the total cost outlined in the electricity invoice by the total electricity consumed (i.e. AUD$/kWh). Ensure the billing period aligns to the consumption period.
	The maximum demand is the amount of energy required by your site at a given time and is measured in kilo volt ampere (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 to understand the required size of the voltage optimisation unit and can assist in the calculation of potential demand charge savings.

Quantify 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. It is recommended you: • 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, etc.); and • Consider available tariffs, if any for your electricity charges • Consider if managing the maximum demand can be an opportunity for your site.

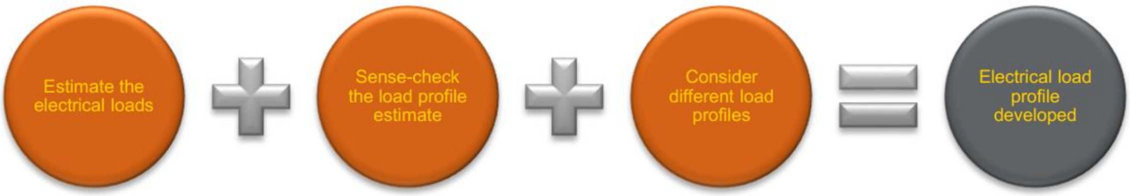
4.3. Stage 3 – Develop an Electrical Load Profile

To complete this stage, you should:

- Understand your site's electricity consumption and cost profile; and
- Ensure the electrical equipment register is complete and accurate.

By completing this stage, you will develop an electrical load profile that will assist you identify key equipment or areas that may benefit from voltage optimisation.

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



	Key steps to estimate an electrical load include:
	• Equipment information - this should be documented as part of the development of an equipment register (as described in Section 4.2):
	  ○ List power ratings (kW) for each electrical equipment considered; and
	  ○ List the number of units.
	• Equipment attributes:
	  ○ Maximum load (kW) – calculated by multiplying the power and number of equipment for each device; and
	  ○ Utilisation factors (%) – how often the electrical equipment is operational during the period evaluated.
	• Load profile estimate:
	  ○ Operating hours over a period of time (e.g. hrs / month).
	  ○ Electricity consumption (kWh) over a period of time (e.g. kWh / month); and
	  ○ Percentage breakdown of electricity consumption by equipment type (e.g. air conditioning uses 30% of the total electricity consumption, lighting uses 35%, etc.).

Sense - check the load profile estimate

Reconcile between 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 perform the reconciliation, it is recommended you:

- Compare the total electricity consumption (in kWh) against the invoice (note it should be over the same period of time),
- Consider whether there may be additional equipment that you might not have considered as part of the assessment (e.g. emergency lighting) - allow for some contingency in the calculation,
- If the estimated electricity consumed and the invoiced electricity consumed don't reconcile, you should vary either the utilisation factor or the operating hours; and
- Sense-check the percentage breakdown of electricity consumption by equipment type.

Consider asking an energy management specialist to assist with completing this step.

Consider different load profiles

Load profiles can vary depending on a site's operations and how the equipment is utilised. Different load profiles can be estimated for different scenarios leading to an increase in assessment accuracy. Therefore, depending on how the equipment is used, electrical load profiles may need to be produced for different operating periods. For example:

- Days vs nights.
- Full production vs reduced production vs idle time.
- Weekdays vs weekends; and
- Winter vs summer.

Develop an electrical load for your site	
	Using the asset register and the key electrical equipment information, you should be in the position to develop an electrical load profile. More details can be found in of the NSW OE&H voltage optimisation guide and an electrical load profile template can be found in **Toolkit 3** of that guide.

4.4. Stage 4 – Review the Voltage Sensitivity of Equipment

To complete this stage, you should have an electrical load profile for your site. Following the development of the electrical load, an evaluation of the equipment voltage sensitivity should be performed. This will be a key input to understand any potential savings resulting from the implementation of voltage optimisation.

Voltage Sensitivity Assessment
Determine the voltage sensitivity of the main electricity consuming equipment installed on site. Refer to Section 2.3.1 for guidance on the sensitivity of the most common equipment types.

4.5. Stage 5 – Calculate Potential Benefits

This last stage of the evaluation step (Stage 5) is to calculate the potential benefits of implementing voltage optimisation. This should be followed by evaluating 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 impacts the power consumed by electrical equipment. Based on 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 on power would be 2%).

$$\boldsymbol{Power\ (W) = \frac{Voltage\ (V)^2}{Resistance\ (R)}}$$

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

- A decrease in electricity consumption by voltage sensitive equipment.
- The potential voltage reduction (e.g. 4.08%); and
- The voltage: power ratio multiplier is (e.g. 2).

4.6. Evaluate Alternative Options

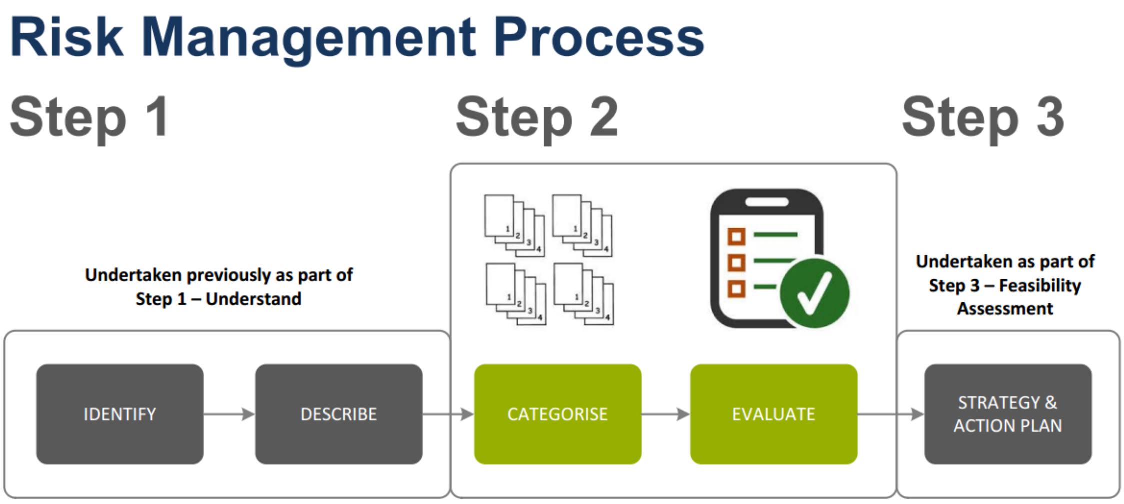
When evaluating an investment, alternative options should be considered to test and evaluate the benefits and risks associated with the option. The investment in energy efficiency options is no different and alternative options should be considered based on the specific circumstances of your site. You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

In order to evaluate different options, the potential energy savings, financial costs and benefits should be considered (e.g. a simple payback period). For example, alternative options to save energy at a site may include the consideration of lighting systems upgrades, HVAC equipment replacement, or variable speed drive (VSD) installations on motors.

> TIP
>
> - *Voltage optimisation should be considered against planned or potential changes to your site (e.g. modifications, replacements, upgrades) and other energy management alternatives.*
> - *If using an independent energy savings professional to perform an assessment of voltage optimisation, request that the assessment considers other energy savings opportunities.*

4.7. Risk Assessment: Categorise and Evaluate the Risks

Following the risk management process introduced in *Step 1*, you should categorise and evaluate the risks previously identified. This should include the following steps:

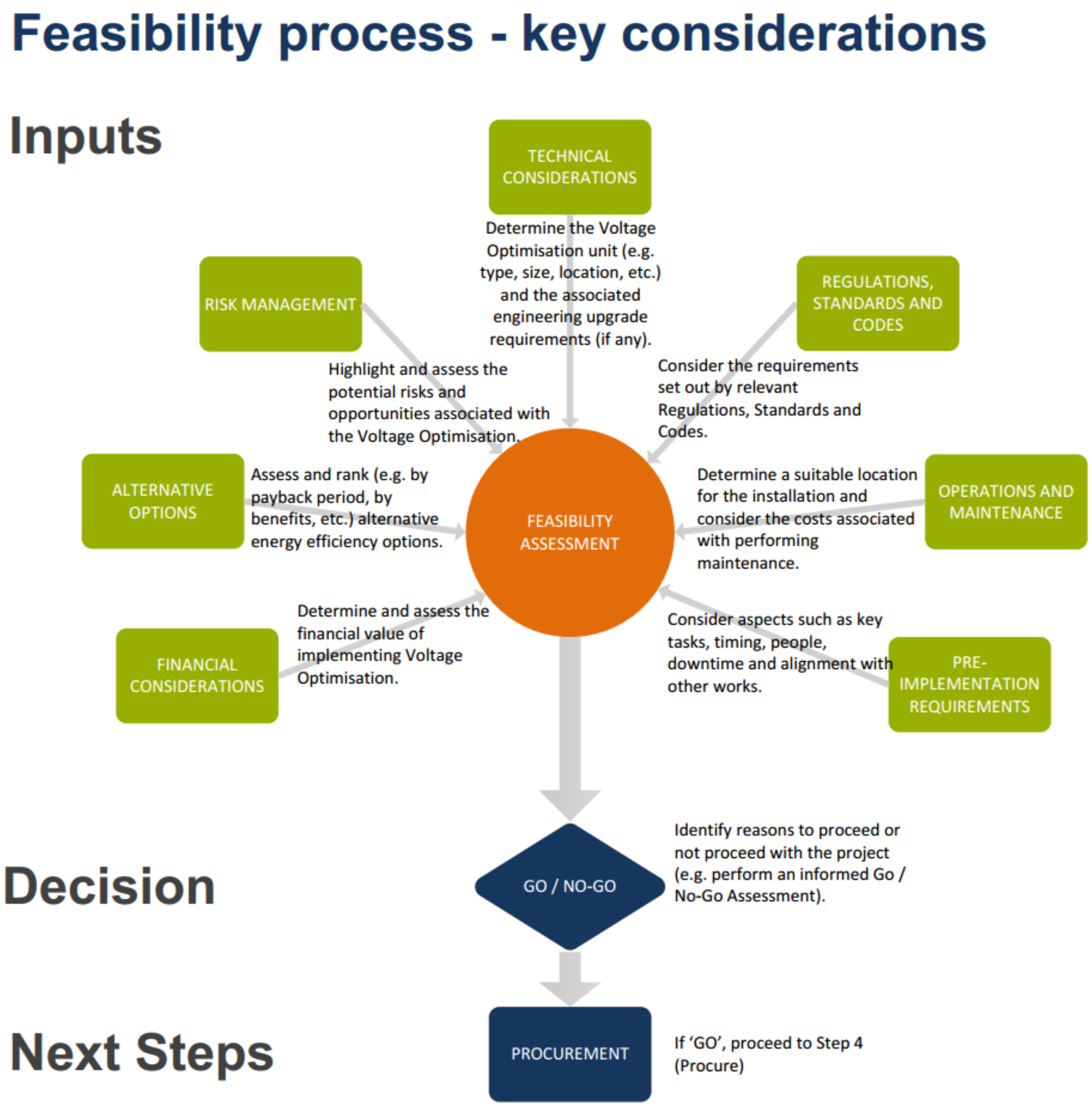


Process	Recommendation
Categorise	Categorise risks to understand the relationship between them (e.g. safety, regulatory, financial, electrical infrastructure, supply etc.).
Evaluate	Evaluate risks and prioritise them based on their criticality. The criticality can be determined based on the likelihood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

> TIP
>
> - *Refer to Appendix A for reference to common issues and risks that can be considered when assessing the suitability of voltage optimisation.*
> - *Refer to Appendix B for example business scenarios to support a decision whether to undertake a more detailed evaluation of voltage optimisation.*

5. STEP 3 - FEASIBILITY

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



> TIP
>
> *Depending on the complexity of your site, it is advisable you engage a specialist to undertake the feasibility assessment to determine the suitability of voltage optimisation.*

5.1. Financial Considerations

You should assess a number of financial considerations to understand the financial impacts of implementing voltage optimisation. Importantly, you should consider the total cost of ownership of the technology. The total cost of ownership considers all costs in addition to the up-front capital costs. The following key considerations should assist you determining the additional costs and financial considerations required to make an informed decision.

Category	Key Considerations
Budget constraints / limitations / targets	• Internal costs • Activities and resources • Performance metrics/hurdles
External costs	• Specialists • Engineering support
Costs	• Up-front capital (CAPEX) • Operating and maintenance costs (OPEX) • Contingency costs
Internal financial considerations	• Simple payback periods • Internal rate of return (IRR) • Total cost of ownership (TCO)
Others	• Built-in contingency (based on an appropriate percentage of the items above). • Consideration should also be given to alternative funding streams (e.g. generation of energy savings certificates).

> TIP
>
> - *Consider the total cost of implementing voltage optimisation at your site. The total cost should consider all additional potential costs to the capital costs of the technology.*
> - *Consider a financial scenario estimating the cost of 'not implementing' voltage optimisation.*

> TIP
>
> *The total cost of ownership (TCO) can be utilised to consider the potential direct and indirect costs associated with the adoption of voltage optimisation.*
>
> *TCO = Capital Costs + Operational Costs + Ongoing Costs*
>
> *Capital Costs:*
>
> - *Purchase of voltage optimisation unit; and*
> - *Engineering works (e.g. civil, electrical).*
>
> *Operational costs:*
>
> - *Procurement costs.*

- *Commercial costs (e.g. warrantee, guarantee, etc.).*
- *Labour costs (e.g. installation, testing, etc.); and*
- *Certification requirements.*

Ongoing Costs:

- *Inspection costs (e.g. inspections over the life of asset); and*
- *Maintenance costs (e.g. regular maintenance costs over the life of asset).*

Other cost considerations such as:

- *Shutdown/downtime required for the installation and commissioning the voltage optimisation unit.*
- *Monitoring and verification.*
- *Spares cost (including the availability of parts).*
- *Training and accreditation requirements; and*
- *Decommissioning costs.*

5.1.1. Indicative Prices for Voltage Optimisation Technologies

Table 1 and provide a summary of the different sizes and indicative costs of dynamic and fixed voltage optimisation technologies, respectively[9]. Costs are given per kVA as well as the total capital cost, considering the installation costs but not the transportation costs as these vary significantly depending on the supplier and location of the installation. These prices can only be viewed as indicative and voltage optimisation technology suppliers should be contacted directly for more accurate prices in a particular circumstance.

Table 1: Indicative prices and installation costs of dynamic voltage optimisation technologies[10,11]

Rated power (kVA)	Average price (AUD/kVA)	Average cost (incl. installation) (AUD)	Minimum cost (incl. installation) (AUD)	Maximum cost (incl. installation) (AUD)
250	145	36,250	24,100	53,300
300	134	40,200	26,700	59,100
500	196	97,600	64,800	143,500
630	189.5	144,000	95,650	211,700
800	168.5	135,000	89,650	198,500
1,000	164.5	164,400	109,200	241,700
1,250	149.5	186,800	124,050	274,550
1,500	212.5	318,700	211,700	468,5600
1,600	157.5	251,400	167,000	369,600
2,000	141.5	283,300	188,200	416,550
2,500	126	315,300	209,450	463,550
3,000	157.5	472,450	313,850	69,450
3,200	105.5	337,850	224,450	496,700
4,000	101.5	406,800	270,200	598,000

[9] Based on general prices provided by voltage optimiser providers and online prices.
[10] Personal communication with industry suppliers (May 2017).
[11] ORTEA. *2014/2015 Price List* [Online]. Available: http://vitasvet.ru/stabilizator_ORTEA/vitasvet.pdf [Accessed 6 April 2015].

Table 2: Indicative prices and installation costs of fixed voltage optimisation technologies[9,12]

Rated power (kVA)	Average price (AUD/kVA)	Average cost (incl. installation) (AUD)
25	150	3,740
135	166	22,400
500	153	76,450
1,000	126	125,800
1,500	114.5	171,650
2,000	106.5	213,100
3,000	103.5	311,150

5.1.2. Economic Feasibility Analysis for Typical Red Meat Processing Facility

The following section presents the results of an economic feasibility analysis to determine whether voltage optimisation can be economically worthwhile for red meat processing sites. Using a typical medium sized (600 head a day) abattoir as the base case a sensitivity analysis has been undertaken to identify the energy savings and payback period with various sensitivity variables to evaluate the cost effectiveness of voltage optimisation technology for abattoirs. Key factors including price of electricity, facility/electrical feeder size (electricity consumption) and load type, supply voltage and optimizer type (dynamic or static) have been analyzed.

5.1.2.1 Standardised abattoir for analysis

The energy savings and simple payback periods presented in the following sections, unless stated otherwise, are based on a typical[13] medium-sized abattoir with an average of 600 head kill/day, operating 5 days per week (250 days per year) with an average supply voltage of 240 V (per phase) and an electricity tariff of $0.15/kWh (including supply charges). Four main transformers[14] are considered for the load, three of which are rated at 1 MVA supplying the refrigeration, kill floor, and by-products feeders and a 1.5 MVA general distribution feeder (also includes some refrigeration loads). The refrigeration loads are considered to contain a high proportion of variable speed drives (VSDs), which is common practice now in most abattoirs. The annual electricity consumption of this representative site is considered to be approximately 15,900 MWh.

5.1.2.2 Annual energy savings and payback period of voltage optimisation technologies applied to different transformers

The annual energy savings and simple payback period for voltage optimisation units installed at typical refrigeration, kill floor, and by-product feeder transformers, as well as for the whole site in a medium-sized abattoir (considering VSDs in loads) is given in Figure 7. Applying voltage optimisation at the refrigeration feeder transformer provides the largest energy savings and shortest payback period compared to the two other types of transformers, even though this transformer contains the highest number of VSDs. Installing voltage optimisation for all the main transformers at a medium sized abattoir also provides a shorter payback period than installing voltage optimisation units at the kill floor or by-products feeder transformers only. This analysis is indicative, based on the example case

[12] NSW Office of Environment and Heritage, "I am your guide to voltage optimisation: is it right for you? available from http://www.environment.nsw.gov.au/resources/business/160226-voltage-optimisation-guide.pdf.

[13] This is based on site visits and data collection from two abattoirs, one in Western Australia and one in Queensland, with kill rates of ~600 head per day, which are considered to be typical medium sized abattoirs.

[14] Based on literature review and data collected from case study sites these transformers cover 88% of the electrical load on site. They also cover the different types of load, for example steady refrigeration load, fluctuating general production (e.g. kill floor. boning room) load and heavy inductive load in the by-products/rendering area.

study site and site owners considering installing VO units should undertake an analysis for their specific site.

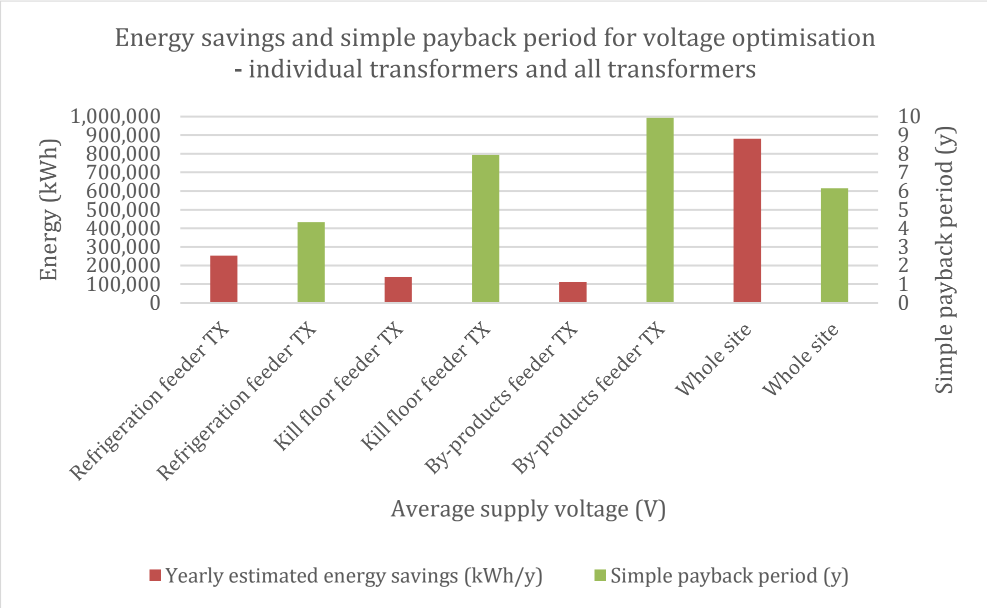


Figure 7: Comparison of annual energy savings and simple payback period for voltage optimisation units installed at refrigeration, kill floor, and by-products feeder transformers (1 MVA units) as well as at the whole site (3x 1 MVA and a 1.5 MVA general distribution transformer).

5.1.2.3 Energy savings and simple payback period of voltage optimisation technologies for a range of supply voltages, with and without VSD loads

The energy savings and simple payback periods for installing voltage optimisation with a set voltage of 220V at a medium sized abattoir is given in Figure 8, where the effect of VSDs in the load is not considered, and Figure 9, where the effect of VSDs on voltage optimisation is considered. The energy savings from voltage optimisation applied to loads with VSDs is estimated in this analysis to be 35% less than loads without VSDs. The energy savings in VSD loads, however, is highly dependent on the type of voltage optimisation technology applied, with some providing little to no savings on VSD loads.

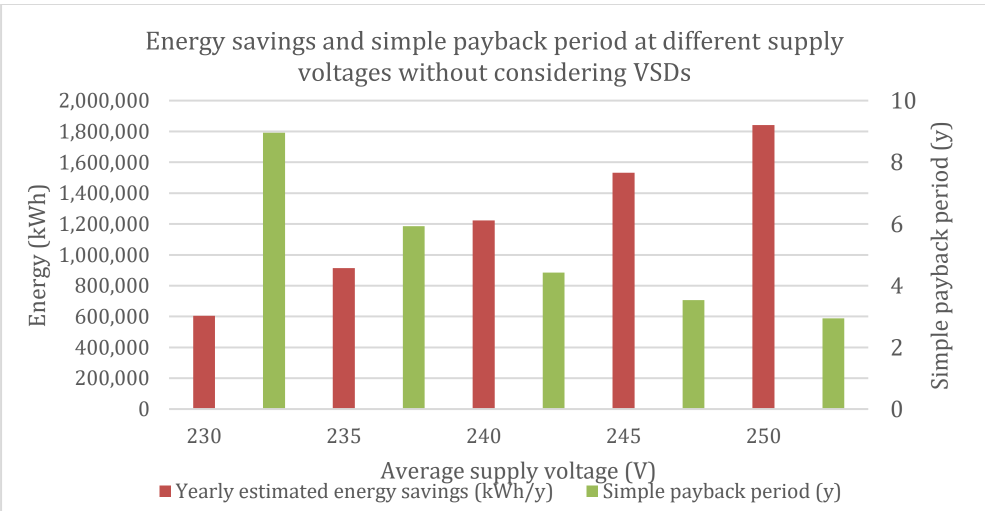


Figure 8: Annual energy savings and simple payback period for a range of supply voltages when applying dynamic voltage optimisation with

a set voltage of 220V installed at a medium-sized abattoir (3 x 1 MVA and a 1.5 MVA unit), without considering the effect of VSDs on the load.

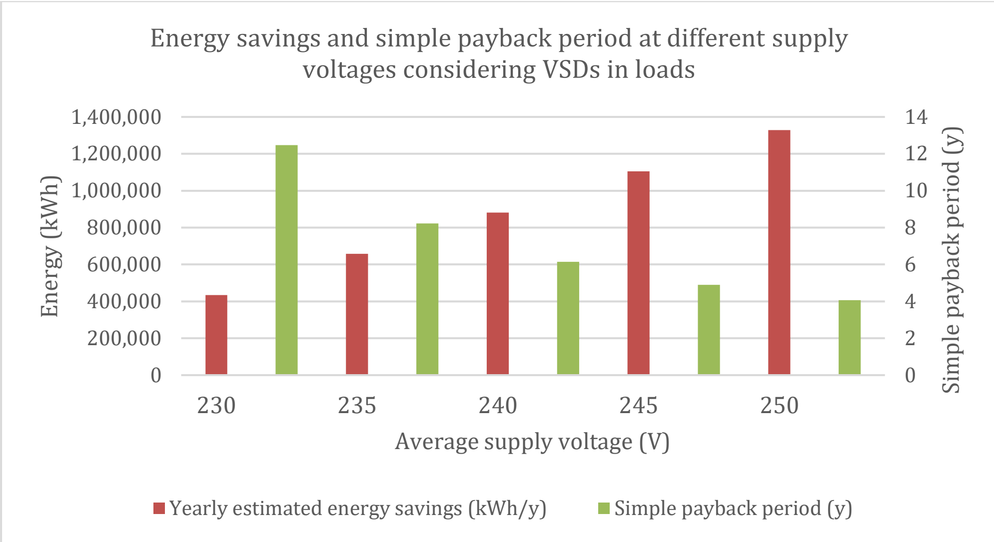


Figure 9: Annual energy savings and simple payback period for a range of supply voltages when applying dynamic voltage optimisation with a set voltage of 220V installed at a medium-sized abattoir (3 x 1 MVA and a 1.5 MVA unit), with consideration of the effect of VSDs on the loads.

5.1.2.4 Comparison of energy savings and payback period of fixed and dynamic voltage optimisation technologies

Energy savings and payback period comparing the introduction of fixed and dynamic voltage optimisation technology for the whole of site case (3 x 1 MVA and a 1 MVA unit) at the standard abattoir are shown in Figure 10.

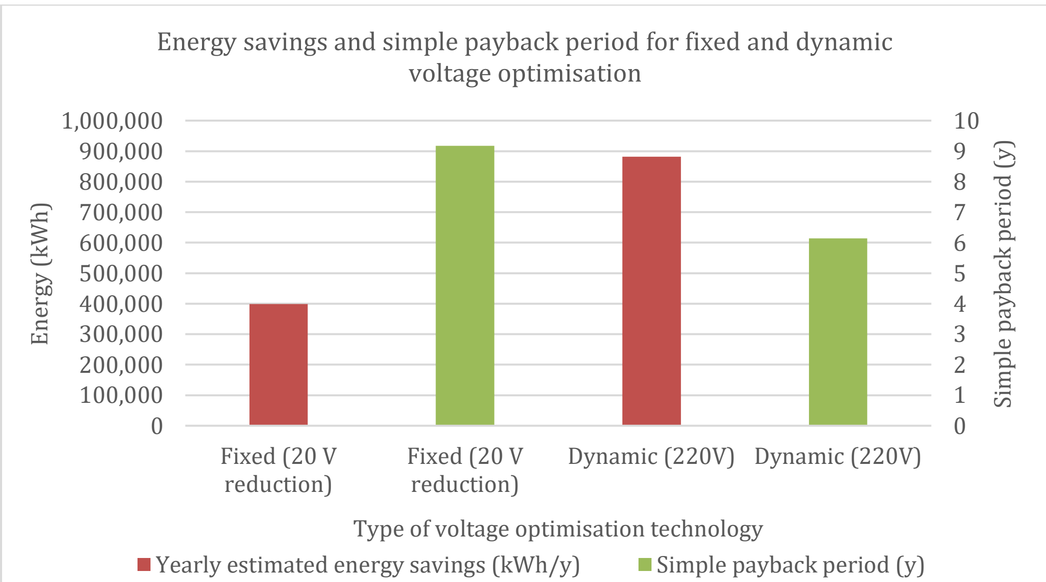


Figure 10: Comparison of annual energy savings and simple payback period when applying fixed voltage optimisation with a 20 V reduction and dynamic voltage optimisation with a set voltage of 220V installed (whole of site) at a standard abattoir.

5.1.2.5 Simple payback period of dynamic voltage optimisation technologies for a range of electricity tariffs

Figure 11 shows the simple payback period for installing VO at the whole of site level for the standard abattoir at different electricity prices (everything else held constant). As would be expected the higher the cost of electricity the more economically feasible the use of VO technology at whole of site level is. The payback period will also vary for installation on individual transformers and this, as well as the whole of site should also be assessed.

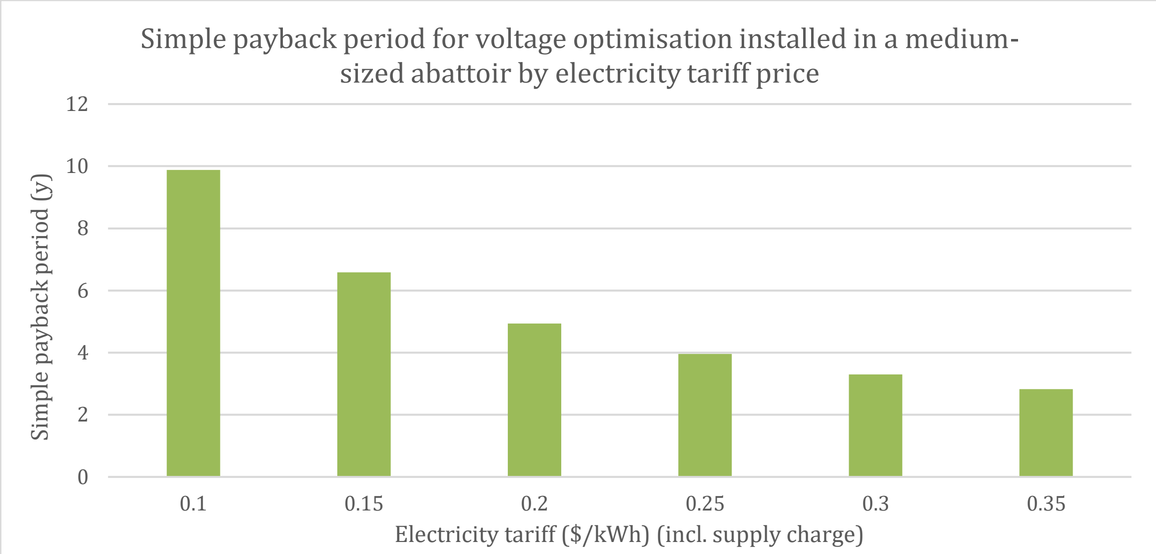


Figure 11: Simple payback period when applying dynamic voltage optimisation (3 x 1 MVA and a 1.5 MVA unit) with a set voltage of 220V installed at a medium-sized abattoir for a range of electricity tariffs.

5.1.2.6 Simple payback period of dynamic voltage optimisation technologies at small, medium, and large abattoirs

Figure 12 compares the simple payback periods for the installation of VO technology at the whole of site level for abattoir sites of different sizes (based on electricity consumption). The larger the site the more economically feasible it is to install VO technology across the whole site.

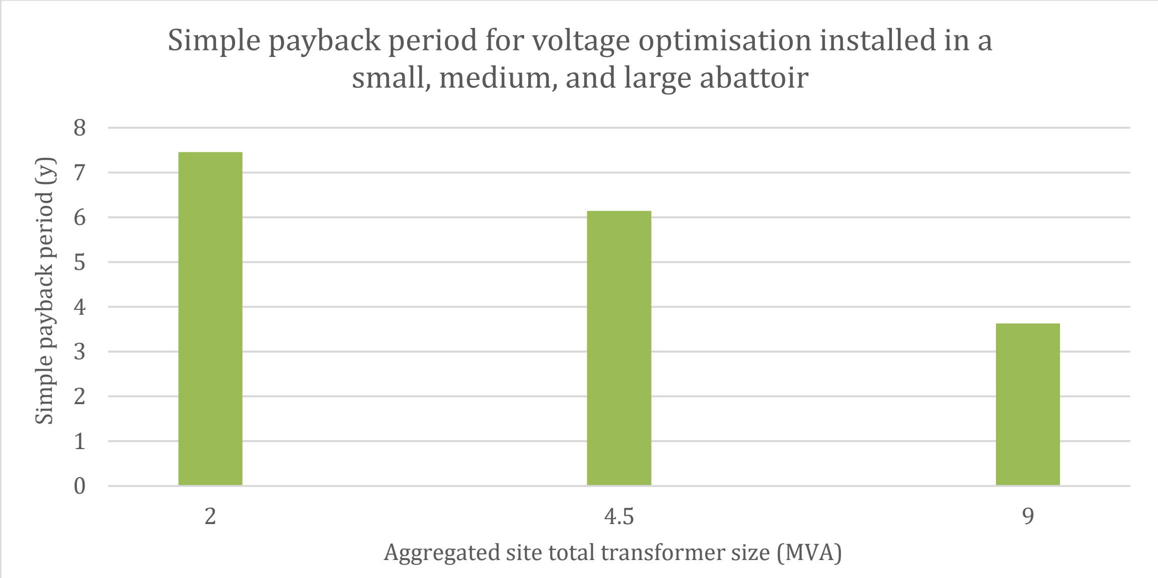


Figure 12: Simple payback period when applying dynamic voltage optimisation with a set voltage of 220V installed at a small (200 head/day), medium (600 head/day), and large abattoir (1,200 head/day) with VO units of 2 MVA (2 x 1 MVA), 4.5 MVA (3 x 1 MVA and a 1.5 MVA), and 9 MVA (2 MVA and 2 x 3.5 MVA), respectively.

As discussed above (section 5.1.2) it may be more economically feasible to install VO technology on individual transformers rather than across the whole site, which can be determined as part of the feasibility study. There are also other non-direct financial benefits of using VO technology, including increased equipment life, reduced maintenance, and depending on the particular technology used, other power quality benefits including improved power factor and reduced harmonic losses.

5.2. Financing Options

There are a variety of energy efficiency and renewable energy financing options available to Australian 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. These are usually state dependent. Appendix D provides an overview of these financing categories.

> TIP
>
> *For more details on how to choose the most suitable financing option for your site, refer to the Energy Efficiency and Renewables Finance Guide (2014) produced by the NSW Office of Environment and Heritage[15].*

5.3. Regulations, Standards and Codes

Under the legislation of all Australian States and Territories, substantial penalties apply for failure to carry out electrical installation work in accordance with regulations and technical standards. These technical standards are the Australia/New Zealand wiring rules and their associated electricity safety legislation.

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[15] **NSW Office of Environment and Heritage "Energy Efficiency and Renewables Finance Guide", 2014. Available from: http://www.environment.nsw.gov.au/resources/business/financing-guide.pdf.**

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

5.4. Technical Considerations

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

- The type of voltage optimisation unit; and
- Specific engineering requirements.

These technical considerations have been explored in further detail below:

Technical Categories	Key Considerations
Voltage Optimisation Unit Type	• Type of unit – consider the selection of the type of unit required (e.g. fixed voltage regulator, dynamic voltage regulator). • Size of unit – consider the size (e.g. kVA rating) of the voltage optimisation unit. The size will depend on its purpose and type. • Compatibility of the unit with other equipment on site (e.g. BMS, IT equipment, production equipment, etc.)
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 structure. Depending on the size and weight of the unit, consideration should be given to 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 / inspections to be performed.

5.5. 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 following key considerations:

O&M Category	Key Considerations
Operations	• System redundancy (e.g. consideration of a bypass switch if 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;

	• Operation impacts if failure occurs.
Maintenance	Whilst direct maintenance requirements are typically low for a voltage optimisation unit, consideration should be given to the following: • Perform periodic inspections (e.g. external checks, internal checks, liquid samples, and performance checks); • Perform annual thermal scan of electricity supply infrastructure (including the voltage optimisation unit); • Maintenance be performed by qualified and experienced personnel; and • Consider planned and scheduled maintenance activities.
Environment	In the event a transformer is replaced considerations should be given to the disposal of the existing unit (e.g. accountability, environmental stewardship, costs).

5.6. Reassess Feasibility with Alternative Options

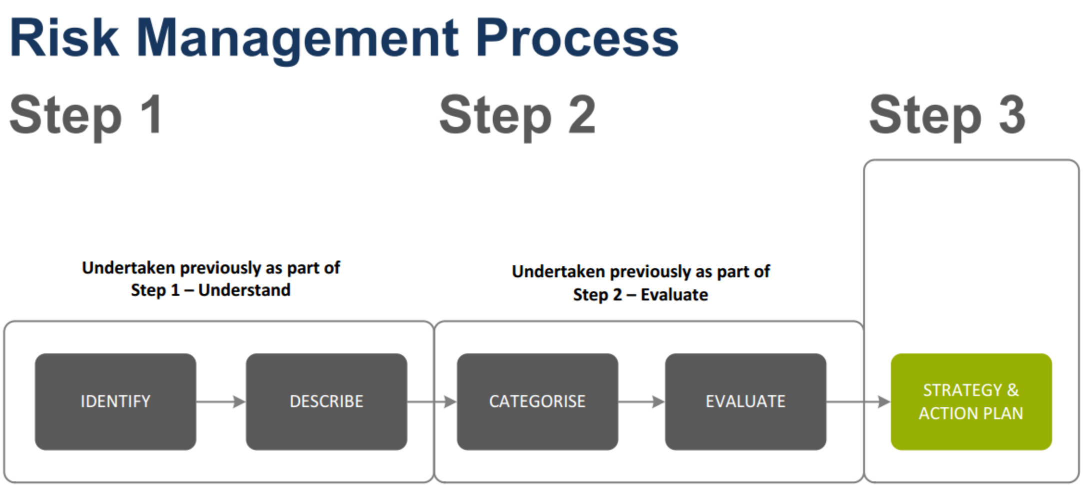
The evaluation of alternative options was performed in *Step 2: Evaluat*e. Nonetheless, it is recommended you re-assess the viability, advantages and disadvantages of voltage optimisation against alternative options. This can be performed by building a matrix which considers the different options against comparative metrics such as energy savings, payback period, etc. Appendix C provides an example decision matrix analysis template.

> TIP
>
> *Document the different alternative options considered and the reason for dismissal of each option as factors or prices may change.*

5.7. Perform a Risk Assessment: Risk Mitigation

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.



WORKING EXAMPLE

Risk Assessment

A red meat processing facility owner has decided to implement voltage optimisation. Due to the criticality of electricity to the business, the abattoir 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 meats, dairy and other perishables which could easily spoil. As such 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:

1. *Defined the risk and the potential consequences;*
2. *Prioritised the risk based on its likelihood (e.g. low) and consequence (e.g. high);*
3. *Developed an action plan to mitigate the risk.*

Mitigation Strategy

Risk Identification		Risk Analysis (Prioritisation)			Action Plan
Identified Risk / Hazard	**Leading to…**	**Likelihood**	**Consequence**	**Risk Rating**	**Mitigation measure (example only)**
Lack of refrigeration system operability	• Site shut down / blackout • Damage to refrigerated stock • Loss of revenue	Low	High	High	• Install a by-pass switch • Emergency back-up power

5.8. Pre-Implementation Requirements

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

- Equipment lead times and spares.
- Civil and electrical work requirements.
- Sequence and duration of installation activities.
- Estimate project constraints; and
- Metering and verification considerations.

> TIP
>
> *It is recommended that performance measurements are established for the project as part of the feasibility assessment. Performance measures can:*
>
> - *Aid in the comparison of planned performance estimates with the actual work carried out;*
> - *Assist with understanding the impact of the project; and*
> - *Assist with project monitoring and verification.*

5.9. Go/No-Go Decision

A go/no-go assessment is the key outcome of this guide. A go/no go assessment considers all the pros and cons of the implementation of voltage optimisation at your site. It is recommended a go/no-go assessment is performed to consider whether to proceed to the procurement step.

You should involve key stakeholders in the go/no-go assessment. If the decision is to:

- Proceed with the voltage optimisation implementation: it is recommended relevant resources (i.e. financial and people) are allocated to the procurement step (*Step 4 –Procure*); or
- Not proceed with the voltage optimisation implementation: it is recommended the reasons for this decision should be documented and communicated to relevant stakeholders.

6. Step 4 – Procure

On the basis of completing Steps 1 to 3, Step 4 aims to guide you through several elements of the procurement of a voltage optimisation unit. This Step provides general guidance and you should always follow your company's internal procurement procedures from. This Step considers:

- Site considerations – focuses on key procurement considerations that you should provide to the product/service providers;
- Product/service provider's considerations – focuses on what you should request / expect from the suppliers; and
- Considerations when selecting suppliers – which should assist you selecting a supplier.

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

6.1. Procurement Considerations: Site Considerations

You should consider the following site procurement considerations when developing voltage optimisation procurement documentation (e.g. tendering documents, specifications, etc.). Product and service providers typically require the information below to be able to supply an accurate proposal. It will also ensure you define the project requirements and expectations.

Focus Area	Key Considerations
Scope of Works	• Outline the intended scope of works for the supplier to follow. • Contain 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, the model, make and minimum recommended voltage of key electrical equipment. • Sub-metered information (if available). • Your site's supply voltage level (if available).
Financials	• Provide information related to your site's electrical expenditure (e.g. electricity invoice).
Commercials	• Provide information related to the preferred warranties, including inclusions / exclusions.

6.2. Procurement Considerations: Product / Service Supplier

You should consider what information to request from the product/service provider(s) when developing voltage optimisation procurement documentation (e.g. tendering documents, specifications, etc.). Some key considerations include:

Focus Area	Key Considerations
Electricity Consumption	• Request clear and transparent calculations regarding potential energy savings / benefits. • Request clear and transparent calculations regarding financial benefits.
Commercials	Request information regarding: • Warranties available, including inclusions/exclusions. • Defects period(s) and duration of claims covered by warrantees. • 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.
Maintenance	• Request the availability and expense of spare parts. • Information on the repairs performed under warranty and the cost of repairs.
Installation and commissioning	• Potential transportation requirements for the delivery of the voltage optimisation unit to site. • Requirements once the equipment has arrived on site (e.g. storage, special tools). • Pre-installation inspections (e.g. identification of damage, compromises to the protective packaging). • Installation and commission requirements (e.g. who, when, how).
Acceptance Testing	• Request tenders to outline the minimum acceptance tests that the manufacturer/supplier must carry out after implementation. • Compare the tests proposed by several suppliers.

6.3. Considerations when Selecting Suppliers

You may find it difficult to choosing which supplier to use. The considerations described below aim to assist you select a supplier.

Focus Area	Key Considerations
Reputation	Some suppliers may have better reviews and referrals than others. You may want to consider the supplier reputation to give you confidence engaging them. It is advised that you 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 its upfront price. Consider the reputation of the voltage optimisation technology manufacturer.

Focus Area	Key Considerations
Guarantees	Some suppliers may offer guarantees on the savings to be achieved. It is recommended that you learn more about how suppliers intend to calculate the guaranteed savings.
Warranties	Some suppliers offer warranties for different timeframes and inclusions. It is recommended that you note any warranty exceptions that are unclear.

TIP

It can be hard to assess key differences between similar voltage optimisation suppliers' options. You should consider the following to perform a comparison between them, for example:

- *The energy consumption breakdown by equipment considered.*
- *The calculation methodology assumptions.*
- *The considered voltage supplied on site.*
- *The voltage sensitivity considered for the equipment on site.*
- *The risks and mitigation strategies proposed by suppliers.*
- *Consideration of a by-pass switch and triggering mechanism.*
- *Installation considerations and requirements; and*
- *Proposed (if any) monitoring and verification of the potential savings.*

7. Step 5 – Implement

Implement (Step 5) represents the final step of the decision-making process. This Step has been developed to provide you with high level considerations that will support you to successfully implement voltage optimisation. This Step details pre-and post-implementation considerations.

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

This Step usually needs careful planning and project management as power outages on site are required. You should consider the implementation work is often undertaken at night to ensure site operations experience as minimal disruption as possible. Furthermore, particulars of the site must be considered, such as on-site electricity generation (e.g. solar PV, co-generation, etc.), potential metering requirements and alterations to existing metering, amongst others.

It is advised to seek an energy specialist that can assist you through this step.

> TIP
>
> *Undertaking measurement and verification activities before the implementation of voltage optimisation will enable an accurate quantification of the electricity consumption impacts on your site.*
>
> *You should continuously manage risks by revisiting your risk register and apply mitigation strategies.*

7.1. Pre-Installation Considerations

Consider the following recommended activities that will assist you to prepare your site for implementation. These include:

Activity	Key Considerations
Measurement and Verification	Measurement and verification is the process of using measurement to reliably determine actual differences in electricity consumption, demand changes, costs, etc. resulting from the implementation of an energy initiative. The NSW Office of Environment and Heritage has a Measurement and Verification Operational Guide[16] which can assist with this process. Additionally, the Energy Saving Scheme (ESS)[17] has a Project Impact Assessment with Measurement and Verification (PIAM&V) method[18]. The PIAM&V method utilises internationally recognised best practice M&V

[16] http://www.environment.nsw.gov.au/resources/energyefficiencyindustry/120990bestpractice.pdf.
[17] http://www.ess.nsw.gov.au/Home.
[18] http://www.environment.nsw.gov.au/resources/business/0047-PIAMV-tool-guide.pdf.

Activity	Key Considerations
	principles. The PIAM&V method applies rigor to verify energy savings and to generate Energy Saving Certificates (ESCs).
Installation Plan	Consider developing an installation plan which can assist ensuring that the installation is completed in a safe and successful manner. Consider the previously assessed information regarding pre-implementation requirements (section 6.7 of this Guide). The installation plan should provide assistance in: • Monitoring contractual performance. • Determining the roles and responsibilities of all stakeholders. • Planning on the activities each stakeholder will perform as part of the installation process; • Managing the relationship with stakeholders. • Managing financial aspects of the installation process. Consider developing verification activities to be performed as part of the implementation of the voltage optimisation. These activities should be agreed between the relevant stakeholders (e.g. the voltage optimisation supplier, installer).

7.2. Post-Installation Considerations

Activity	Key Considerations
Measurement, Monitoring and Verification	• Perform verification activities on measured data to ensure the claimed savings have been achieved. • Continue to monitor the electricity consumption at your site. • Consider the monitoring of performance, particularly during the defects and warranty period of the equipment. • Consider seasonal variations and internal activities (e.g. increase in operational hours) that may impact the electricity consumption.
Maintenance	• Consider the maintenance requirements of the voltage optimisation unit(s). These may include periodic inspections, cleaning, testing etc. • Ensure maintenance activities are formally planned and scheduled.

WORKING EXAMPLE

An abattoir 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. Based on the estimate, business budgeted to spend $3,700 in maintenance costs over a 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 Cost	$100	80%	4.0	$320
Spare Parts	$500	20%	0.2	$20
Potential cost p.a.				$740

**note: maintenance costs will vary depending on your business, unit type and supplier.*

8. Summary

There are no technical reasons why voltage optimisers should not be installed in red meat abattoirs, and there are in fact many advantages to doing so. Apart from the savings in energy these include less stress on electrical equipment and therefore improved lifetimes with less maintenance, as well as (depending on the technology used) improved power factors and less loss due to harmonics.

Economic analysis has shown that for a typical mid-sized (600 head a day) abattoir with a supply voltage of 240 volts and an electricity price of $0.15 a kWh installation of a voltage optimizer will have a payback period of between 3 and 6 years, depending on the supply voltage, type of feeder line and number of VSDs installed. Due to their larger electricity consumption, larger abattoirs will have a lower payback period, as will the use of voltage optimisers on individual large electricity feeder lines, such as refrigeration, compared to the whole site. The use of dynamic voltage optimization is more economically favorable than using voltage reduction. There is significant benefit from the higher uptake of voltage optimization within the red meat processing industry, as has been done in many other industries.

Due to the variation in technologies in the marketplace, and the individual electrical profile of each site, it is important that abattoirs undertake a detailed feasibility analysis before deciding to install a voltage optimizer. This Voltage Optimisation Guide has been prepared to provide the required knowledge about voltage optimisers and how to implement them specifically for the red meat industry. By providing some practical examples, case studies and responses to common questions, the Guide can be used to provide direction and justification for investment (e.g. performing a detailed feasibility assessment) in voltage optimization at red meat processing facilities.

Appendix A – Potential Issues

The table below provides an example of common issues and risks that could be experienced and should be accounted for 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. It is strongly recommended that a site-specific risk assessment is performed. As the voltage optimisation assessment progresses through each of the steps, an issues register should be updated to ensure risks are identified, qualified and mitigated.

Issue	Description
Site Issues	
Site plans / strategies	Changes to a site, for example operational improvements, life of asset changes, production variability, changes to lease periods etc., may impact the feasibility of installing a voltage optimisation unit. The impacts of voltage optimisation should be considered against current and future site plans / strategies for your business and your site. This is important as it may impact energy and cost saving expectations.
Equipment Upgrades	Equipment upgrades, retrofits, replacements etc. may impact the effectiveness of voltage optimisation. For example, the following scenarios may impact the effectiveness of voltage optimisation: • The replacement of an uncontrolled inductive motor for an efficient motor controlled by a VSD. • The upgrade of voltage sensitive magnetic ballast lighting for voltage non-sensitive LEDs. Voltage optimisation should be considered against future plans of the site including equipment upgrades. When considering voltage optimisation, ensure planned equipment maintenance and replacement schedules are considered as part of the decision-making process.
Over-voltage	Over voltage is excess voltage characterised by swells or surges in an 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; or • Production and operation impacts Refer to section 2.1 for potential issues. When considering voltage optimisation, understanding your current voltage supply levels is important along with noting any voltage issues associated with the site.
Under-Voltage	Under voltage is a loss of voltage characterised by sags or dips in an electric circuit. Depending on the length of time of the event, it may cause: • Lack of sufficient power to operate an electrical equipment. • Reduced motor torque. • Electric circuit overheating. • Reduced equipment operating life; or • Production and operation impacts.

Issue	Description
	Refer to Section 2.1 for potential issues. When considering voltage optimisation, understanding your current voltage supply levels is important along with noting any voltage issues associated with the site.
Voltage Optimisation Issues	
Security of Supply	Voltage optimisation units are positioned upstream of an electric circuit. Therefore, the units are positioned in an electric circuit that supplies electricity to an entire site or to a specific area. If a failure occurs to the voltage optimisation unit, your business can be significantly impacted (e.g. equipment downtime). Redundancy measures should be considered to mitigate this risk (e.g. installation of a bypass switch).
Sizing	The selection of a voltage optimisation that is incorrectly sized for the application may lead to equipment failure. A key feature of undertaking a detailed feasibility assessment is to determine 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 associated with benefits associated with voltage optimisation.
Feasibility Assessment	Ensure experienced and qualified personnel are involved in the decision-making process to test the sensibility and appropriateness of voltage optimisation. It is recommended the use of an in-house or independent specialist to determine the feasibility of the technology and to develop specifications for the site (e.g. size of unit, location).
Ownership	A lack of ownership within the organisation may lead an increase in risk associated with project. Where possible, accountability and responsibility should be allocated to personnel during all steps within a 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 consider alternative measures to make an informed investment decision. For example, a site may achieve greater benefits through other technology upgrades such as the installation of VSDs on motors and 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 under-voltage events. Voltage boosters may be required which incur add additional costs.
Installation	Contingency plans should also be considered when planning the installation. The installation of voltage optimisation requires the electrical circuit to be isolated, therefore contingency plans need to be considered. For example, backup power is typically required for emergency systems, refrigeration units containing perishables etc. If there is a longer than planned installation, your site's operations will be impacted. The planning should also consider the need for testing downstream equipment and also operating equipment back to a steady state.
Operations	Operational issues may include: • A voltage optimisation unit may fail causing operational disruptions.

Issue	Description
	A mitigation strategy commonly employed is the installation of a bypass switch. • An under-voltage event may occur (e.g. below recommended equipment ratings) causing equipment damage. This can be mitigated by installing a voltage booster.
Maintenance	A maintenance regime is recommended to ensure the voltage optimisation unit is performing to the business expectations and to mitigate potential issues. Whilst voltage optimisation units typically require minimal maintenance, the units (and consequently your site) may need to be de-energised to be able to perform maintenance. Important: inspections should only be undertaken 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. • Supporting services lead times (e.g. spare parts availability). • Defect liability period. • Compliance with legislative requirements and standards. • Financial strength of the business; or • Proven track record.

Appendix B – Scenario Planning

The table below provides an example of common scenarios that could be encountered when implementing voltage optimisation. Importantly the table has been developed for guidance purposes only. Your site will have unique characteristics and challenges that will need to be considered. As such it is strongly recommended a site-specific risk assessment be performed to consider possible scenarios and risks.

Scenario	Reasoning
Potentially SUITABLE Scenarios	
Your site has a high proportion of voltage sensitive equipment	Sites with a higher proportion of voltage sensitive equipment are the most likely to reduce energy consumption and costs.
The majority of electricity consumption is attributable to voltage sensitive equipment.	If the majority of 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 high number of motors (e.g. HVAC and refrigeration).	Motors that are part-loaded result in energy losses. A voltage optimisation unit may lead to potential 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 maintenance costs of certain equipment. Some sites may value voltage optimisation for this reason over its energy saving potential.
Potentially UNSUITABLE Scenarios	
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 total electricity consumption it may be more beneficial to upgrade equipment than installing a voltage optimisation unit.
Your site mainly utilises voltage non-sensitive equipment.	Savings received from a voltage optimisation unit may be reduced if a high proportion of equipment is non-sensitive to normal voltage changes
The business may not be at the site for an extended period of time.	If a business has plans to move in the immediate future the benefits of voltage optimisation may be reduced
The business is considering other energy efficiency upgrades.	If the business implements new energy saving equipment concurrently then it will be difficult to assess the impact of voltage optimisation. Additionally, changes to a site may decrease the overall sensitivity of a site to voltage optimisation.

Appendix C – Decision Matrix Analysis Sample

A decision matrix analysis can assist you in deciding which energy opportunity might be most viable. You may want to compare several opportunities and apply a weighting factor.

Rate each element on a scale of zero (not suitable) to three (very suitable).

Option	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 Implementation
Voltage Optimisation	3	2	3	2	2	2	0	1
Solar PV	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

Note: The numbers in this example should not be considered as representative of actual suitability for an energy saving opportunity. Suitability of different opportunities is dependent on your site.

You must determine which factors have greater weighting of importance. A scale of one (not important) to five (very important) can be used. By multiplying the suitability factor by the weighting factor, the weighted total can be used to help support decision-making.

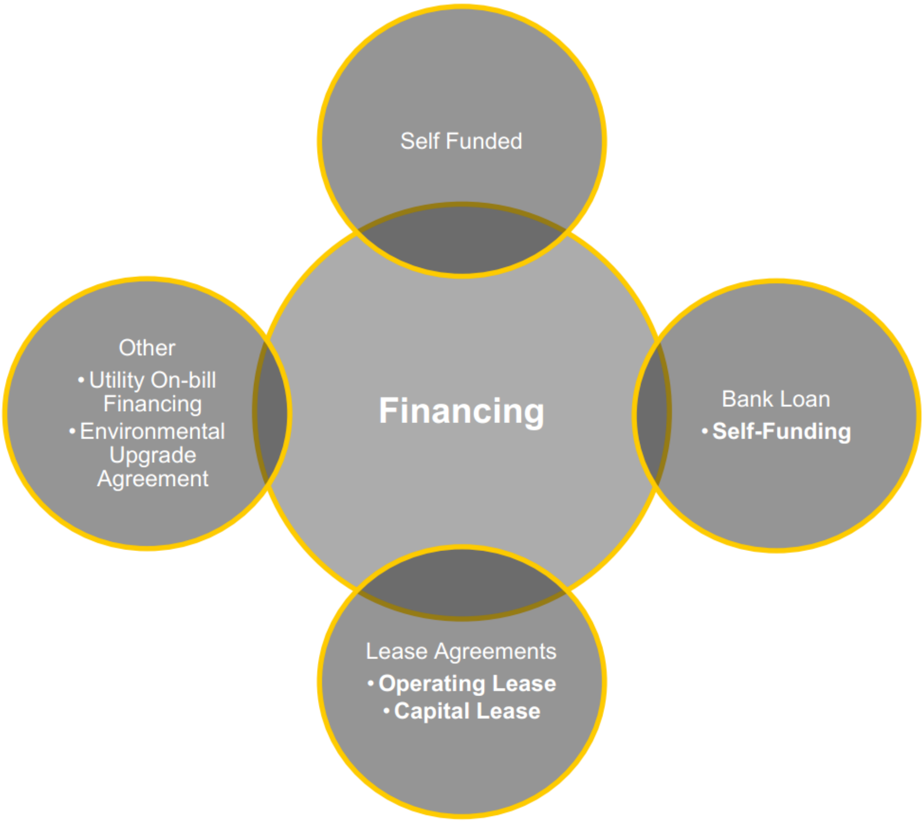
Option	Electricity Saving [MWh] p.a.	CAPEX [AUD$]	OPEX [AUD$]	Total Cost Savings $ p.a.	Simple Payback (years)	GHG savings (tonnes CO_2) p.a.	Risk to Existing Equipment	Ease of Implementation	Total
Weight (1-5)	3	5	3	5	5	1	4	3	-
Voltage Optimisation	9	10	9	10	10	2	0	3	53
Solar PV	6	5	3	10	0	3	4	3	34
Lighting Retrofit	6	15	9	10	10	2	12	6	70
HVAC Replacement	3	15	0	5	5	1	8	3	40

Note: The weighting in this example have been determined arbitrarily. You should consider what weighting it places on each factor it chooses to assess. The results provided in this example do not represent the actual suitability for an energy saving opportunity

Determining the total weighted result may provide an indication of what 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 most attractive technology is voltage optimisation. The user will need to weight which opportunity may be selected for further evaluation / implementation.

Appendix D – Financing Voltage Optimisation

A variety of energy efficiency and renewable energy financing options are available to Australian businesses. These options generally fall into four categories:



The financing options are summarised below:

Type	Financing Option	Description
Internal	*Self-Funding*	An energy efficiency project that is financed 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. Whilst the loan offers reduced initial costs to the business, the customer assumes risk and may be required to offer collateral.

Type	Financing Option	Description
Lease Agreements	*Operating Lease*	A lease whereby 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 as well as 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. Other key difference is that customers can depreciate the unit.
Other	*Utility On-Bill Financing*	This is where an energy retailer installs the voltage optimisation unit and this is 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 which is paid back to a local council via charges over time. Whilst the rates and terms offered are better for businesses than other loans, only some councils offer this service.