# Part 1 – Summary Table

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| **Submission for the Creation of a New Activity or Amendment of an Existing Activity under the ESI Scheme** |
| **Applicant details** |
| Date of submission | 11 December 2015 |
| Company name(if applicable) | Edge Electrons Pty Ltd |
| ABN/ACN(if applicable) | 94 168 621 565 |
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| **Contact person details** |
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| **Summary of proposal**Please provide evidence, data or references to justify all claims made.The suggested elements of a response are provided in italics. The text in italics may be deleted in the submission. |
| **Category of proposed activity** | Conservation Voltage Reduction (CVR) for Households |
| **Confidentiality statementMUST BE COMPLETED**In lodging a submission, parties acknowledge the Department's right to engage consultants and contractors to assist in the assessment process, and to disclose information (that might otherwise be identified as confidential by a party) to such persons for those purposes. | The section on “Project Uptake” is confidential. |
| **Briefly describe new or amended activity**Maximum 100 words. | The installation of a conservation voltage reduction (CVR) unit at a residential site connected to the low voltage distribution network. |
| **Estimate the average annual energy savings for an average installation of that activity** | A typical residential installation would be a 5kVA conservation voltage reduction (CVR) unit, which would save approximately 5% of annual energy, or 0.5MWh per year, over 20 years. That installation would be eligible to create 11 VEECs.(see Part 2 for detail) |
| **Demonstrate that the activity is likely to be additional to business as usual (BAU)** | There is currently no small market for CVR equipment for residential customers. All activity under this method would be additional. |
| **List the key variables that should be considered to ensure the activity best represents the delivered energy savings** | The main variable to be considered is the rated power capacity of the CVR equipment (in kVA).Savings will also depend on where the site is located in the distribution network (metropolitan or regional). |
| **List all existing product standards which support the claims for energy savings or related matters** | Compliance to AS/NZS 3100:2009 Approval and test specification—General requirements for electrical equipmentInput voltage: between 216 V and 253 V.Line surge protection: tested in accordance with IEC 61000‐4‐5:2014 Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity testEfficiency: at least 98% at 50% load.Must be able to dynamically adjust output voltage to changes in supply voltage.Must be able to bypass supply voltages below 216V.Output: Must have an output voltage tolerance of + / - 3% at 225V. |
| **Ensuring savings are valid** | The installation can be verified by photographic evidence of the installation and equipment.Site audits could be conducted either by physical inspection of the equipment and measurement of output voltage. Some equipment will allow remote monitoring through integrated communications, which will simplify verification and audit. |
| **Protecting health and safety** | The activity requires equipment to be installed behind or in front of the meter at the main switch board. This requires the supervision of a licensed electrician. A certificate of compliance for electrical works will be supplied. |
| **Other benefits and issues** | This activity has a typical 2 to 10 year payback. There is potential for hundreds of thousands of installations in Victorian homes annually, creating hundreds of thousands of VEECs per year.Other benefits include:- reduced harmonics- surge protection- solar PV grid integration- increased electrical equipment lifetime due to lower operating stresses (e.g. less heat)- sales and installation jobs- greenhouse gas benefits- air pollution benefitsThis proposed activity is not included in other state energy efficiency schemes at the moment. |

# Part 2 – Claims against assessment criteria

## A – Estimate of average energy and greenhouse savings

**Overview – how CVR saves energy**

The voltage supplied to homes in Victoria depends on how far the home is situated from the nearest distribution transformer. Voltages decrease with distance from the distribution transformer. Homes close to the transformer will have a high supply voltage, and homes further away will have a lower voltage. In order to ensure that every household has sufficient voltage to run their appliances, the distributors are required to ensure that electricity is supplied within a range of values.

In Australia, electricity is required to be delivered to the premises point of supply (main circuit board) at a nominal voltage of 230V with a tolerance of + 10% and – 6%, i.e. voltages between 216V and 253V.

Voltage also drops between the point of supply and the individual power sockets and fixed appliances in the house. Australian Standard *AS/NZS 3000:2007 Electrical installations (known as the Australian/New Zealand Wiring Rules)* requires wiring voltage losses between the main circuit board (point of supply) and any point in the electrical installation to be no more than 5%.

The end result is that electricity is typically supplied to premises in Victoria at a voltage much higher that required for optimal operation of appliances. The additional power is wasted as heat.

Conservation Voltage Reduction works by continually monitoring the supply voltage and stepping it down to ensure that it is tightly targeted to the optimum level for the electrical installation.

The unit will automatically bypass if the maximum kVA power is exceeded for a sustained period, as the unit could overheat otherwise. The CVR unit will also be bypassed if the supply voltage drops below the minimum voltage. It is important, therefore, that the CVR unit is correctly sized for the household load.

Generally speaking, when voltages reduce, so too does the power drawn. For a simple resistive load (R), power (P), and energy consumption, reduces with the square of the voltage (V):

P = V2 / R

For small changes in voltage, the savings have a roughly linear relationship with the voltage reduction.

Modern electrical equipment includes electronic equipment that does not necessarily follow this simple relationship. Nevertheless, power savings have been observed across a wide range of electrical devices.[[1]](#footnote-1)

Motors tend to have maximum efficiency at their rated voltage, with current increasing both above and below that voltage, but with power reducing with voltage.[[2]](#footnote-2) Conventional air conditioners show a similar relationship.[[3]](#footnote-3)

Some devices that will deliver reduced service levels when voltage is reduced, effectively bringing performance back down to its expected rated service levels. For example, a 35W halogen light might actually consume 40W of power under raised voltage, and output more light than its rating. Reducing the input voltage to the rated 230V will also reduce its light output to the rated value of luminous flux (lumens). This does not effectively reduce service levels unless the required service levels of the equipment was underestimated at the time of installation.

In addition, for resistive heating devices such as electric resistance water heaters, electrical slab heating, ovens and electric cooktops, any voltage reduction will result in reduced power draw, but will also mean it takes longer to heat up, so the actual energy savings are zero.

Resistive heating elements also usually draw high power, so it is recommended that CVR equipment is not connected to any circuits for hot water, cooking or slab heating.

In summary, the different types of loads and the results of reduced voltage can be summarised as follows:

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| --- | --- | --- | --- |
| **Type of load** | **Examples** | **Effect of CVR** | **Energy savings** |
| **Incandescent lighting** | Halogen downlights | Reduction of service levels to rated luminous flux | Proportional to voltage reduction |
| **Discharge lighting** | Fluorescent lights | Reduction of services levels to rated luminous flux | Proportional to voltage reduction |
| **Resistive heating** | Water heaters, clothes dryers, ovens | Reduces the power, but increases the time taken to heat the water or air | No savings |
| **Motors** | Refrigerators, air conditioning, washing machines, pool pumps | Reduced torque, optimum electrical efficiency achieved at rated voltage | Generally proportional to voltage reduction |
| **High efficiency motors** | Variable speed drives or inverters | Will draw higher current | No savings |
| **Electronics** | IT, audio-visual, LED lights | Some savings, although some electronic transformers or drivers will draw higher current to compensate | Some savings, maybe non-linear. |

As household appliances become more efficient, the opportunity for savings from CVR will reduce. However, contemporary houses still have many opportunities to save energy through CVR, as has been found in field trials.

**Key parameters**

*Equipment power rating* (kVA) is the rated apparent power that the CVR equipment can service. This is determined by the manufacturer. This is related to the current throughput that can be sustained before the unit begins to overheat.

*Equipment efficiency* = 0.98. State-of-the-art CVR equipment generally has an efficiency of between 98% and 99%. However, this value is not used in the calculation, as the energy savings measured in studies are net of the CVR equipment losses.

*Annual energy consumption* for a residential dwelling can vary significantly. For example, the VEET activity for In-home Display Units differentiates two different consumption profiles, depending on whether or not the household has access to reticulated gas.[[4]](#footnote-4) This can simply be established by the postcode of the household. However, there are many more factors that could be taken into account, such as climate, floor area, age of building, occupancy during the day etc. that also have a large effect on household energy consumption. Instead, it is proposed to use the rated capacity of the CVR unit to estimate the amount of energy throughput that the equipment services. Since VEECs will only cover a proportion of the installation costs, there will be no incentive to oversize units, and the compliance regime will ensure that units are not undersized.

*Effective full-load hours* (or EFLH) is the equivalent number of hours per year that the CVR unit would need to operate at full rated capacity to have the same throughput of energy as a full year of actual energy profile. The effective full-load hours is a measure of the “peakiness” of the load profile. Residential load profiles are quite peaky, as seen in Figure 1 below, with a distinctive morning and evening peak.

Figure 1 - Daily electricity in one Victoria household, 5 May – 19 June 2012 (Source: Victorian Government)[[5]](#footnote-5)



Analysis of this example profile reveals it is the equivalent of 3000 hours per year at the peak average demand of 3.5 kW. Any residential load with a similar load profile will have the same 3000 hours of equivalent full-load use.

*Effective full-load hours = 3000 hours*

*Savings factor* = 5.04%. There have not been many comprehensive trials of residential CVR. A detailed UK study found savings of 6.3% savings attributable to homes that don’t use electrical space heating.[[6]](#footnote-6) This study looked at reducing the grid voltage from an average of 245V to 220V. If instead, the voltage is reduced to the lower end of the preferred voltage range under the Australian standard of 225V, it is expected that the savings would be reduced proportionally (to four-fifths). This yields a savings value of 5.04%.

The UK average supply voltage of 245V is valid for Victoria, and perhaps conservative. Most networks were designed to deliver to the old nominal voltage of 240V + / = 10% (i.e. up to 264V), and there are many instances of supply voltages above 255V across Australia. Ausgrid, in NSW, has reported that its current average network voltage is 250V.[[7]](#footnote-7) Supply voltages are also being driven up by the increased penetration of solar PV in the distribution network. Energex, in Qld, has reported average network voltages of 254 V in parts of its network.[[8]](#footnote-8) An average supply voltage of 245V is considered conservative.

The Government could consult with networks to provide more evidence of the level of voltages and the effects of solar PV inverters on the network and opportunities for CVR to address these issues.

*Load power factor* = 0.9. This is the ratio of active power to apparent power for a typical residential load. CVR equipment is rated according to the maximum current it can sustain without overheating, which is related to the apparent power (kVA) of the load rather than the active power (kW). A typical value for residential loads is 0.9.[[9]](#footnote-9)

*Derating factor* = 0.8. CVR equipment is rated at a certain capacity. It is likely that CVR will be slightly oversized, to accommodate daily, weekday and seasonal variation in average maximum demand as well as because standard equipment only comes in certain capacity sizes (e.g. 2 kVA, 3kVA, 5kVA), requiring the next highest capacity size to be chosen. We have assumed that, on average, the CVR equipment is 25% oversized, requiring it to be operated at a level derated to 0.8 of rated capacity.

*Equipment lifetime* = 20 years. Equipment lifetimes have been estimated as long as 51 years based on component analysis.[[10]](#footnote-10) Typical warranties are between 10 and 15 years.[[11]](#footnote-11)

*Regional loss factor* differs for metropolitan and regional areas, consistent with VEET.[[12]](#footnote-12)

* Metropolitan = 0.98
* Regional = 1.04

*Greenhouse gas abatement coefficient for electricity* = 1.095, consistent with the proposed update to VEET.[[13]](#footnote-13)

**Greenhouse gas abatement calculations**

Greenhouse gas abatement (tCO2-e)

Greenhouse gas abatement = Electricity Savings x Regional loss factor x Greenhouse gas abatement coefficient for electricity

 = Electricity savings x Regional loss factor x 1.095

Electricity savings (MWh)

Electricity savings = (Annual electricity consumption) x (Savings factor) x (Equipment Lifetime)

 = (Annual electricity consumption) x 0.0504 x 20

 = (Annual electricity consumption) x 1.08

Annual electricity consumption (MWh)

Annual electricity consumption = (Equipment capacity) x (Load power factor) x (Derating factor) x (Effective Full-load Hours) / 1000

 = (Equipment capacity) x 0.9 x 0.8 x 3000 / 1000

 = (Equipment capacity) x 2.16

Greenhouse gas abatement (simplified)

Greenhouse gas abatement = (Electricity savings) x (Regional loss factor) x 1.095

 = (Annual electricity consumption) x 1.08 x (Regional loss factor) x 1.095

 = (Equipment capacity) x 2.16 x 1.08 x (Regional loss factor) x 1.095

 = (Equipment capacity) x (Regional loss factor) x 2.384

**Mandatory requirements**

There are no mandatory requirements for consumers to install conservation voltage regulation equipment.

**Rebound**

There is not expected to be any rebound in energy use from this activity.

## B – Implementation of the proposed new ESI activity

**Installation requirements**

The Conservative Voltage Reduction (CVR) equipment must be installed:

* By, or under the supervision of, a licensed electrician.
* On main switchboard for the site, where low voltage electrical supply enters the site.
* With any necessary approvals from the relevant Distribution Network Service Provider for the site.
* To comply with AS/NZS 3000:2007 Electrical installations.
* In conformance with any rules under the Victorian Service and Installation Rules and the Victorian Electricity Distribution Code.
* Must be sized to serve at least 90% of expected annual demand.
* Must have a bypass for supply voltages below 216V.
* Output voltage must be set to 225 V (or lower, with the agreement of the customer).

Australian Standard *AS 61000.3.100–2011 Electromagnetic compatibility (EMC) Part 3.100: Limits—Steady state voltage limits in public electricity systems* stipulates a preferred range of + 6% to – 2%, i.e. voltages between 225V and 244V. It is recommended to use the bottom of this preferred range for calculating savings under VEET. However, in many instances sites operate well with voltages of 220V or less. This can be negotiated with the customer.

If on independent circuits, the following loads must not be supplied by the CVR unit:

* Electric hot water
* Electric showers or instantaneous hot water heaters
* Electric ovens and/or cooktops
* Electric resistance slab heating

The site will need to be de-energised during the installation, which may need to be arranged with the customer.

**Verification of installation**

Evidence to establish the key parameters for an installation are outlined in the following table.

|  |  |
| --- | --- |
| **Key parameter** | **Evidence** |
| **CVR unit power rating** | Manufacturer’s specificationTest reportPhotograph of installed CVR equipment |
| **Site location** | Site address, including postcodeBusiness name and ABN |

**Site audits**

The installation can be verified either by physical inspection of the equipment or by smart meter measurements (if installed in front of the meter).

Physical inspection will verify that the equipment is installed. However it cannot show that the CVR equipment is functioning correctly. Submetering could be performed during the site inspection to confirm this, but may be costly.

**Business case**

The installed cost of CVR equipment is generally quoted at between $150 and $300 / kVA of rated capacity, but can be as low as $100 / kVA for the latest technology.[[14]](#footnote-14)

*Households*

A family in a large house may use around 10 MWh of electricity per year.

|  |  |
| --- | --- |
| **Customer** | **Household** |
| **Annual energy consumption** | 10,800 kWh |
| **Average maximum demand** | 3.5 kW |
| **Load power factor** | 0.9 |
| **Electricity tariff** | $0.25 / kWh |
| **CVR equipment power rating** | 5 kVA |
| **CVR equipment cost** | $500 |
|  |  |
| **CVR energy savings** | 0.544 kWh / year (5.04%) |
| **Energy bill savings** | $136 / year |
| **Payback without VEECs** | 3.7 years |
|  |  |
| **Potential VEECs** | 11.7 |
| **VEEC value** | $234 |
| **CVR cost after VEECs** | $266 |
| **VEEC discount** | 46.7% |
| **Payback with VEECs** | 2 years |

**Market opportunity**

All residential customers in Victoria can benefit from conservation voltage reduction (CVR). There is no current market for residential CVR. The emergence of residential sized units will change that.

There are approximately 2 million occupied private dwellings in Victoria.[[15]](#footnote-15) On average, those dwellings can save 5% of 5,882 kWh of non-heating-related electricity or 593,000 MWh per annum. When deemed over 20 years and converted to VEECs, this equates to potentially 13 million VEECs that could be created from residential CVR equipment installation. A 10 year roll-out program could produce 1.3 million VEECs per year to support the targets.

**Industry benefits**

At the moment, CVR equipment is manufactured overseas and imported to Australia. However, it is manufactured in some comparable economies, such as the United Kingdom, so it is possible that some manufacturing could take place in Australia in the future.

Most jobs in CVR in Victoria will be through the sales and installation of the units, located wherever those installations take place.

# Part 3 – Additional Considerations

## A Quality standards

The CVR equipment must have had its performance tested to meet the following conditions and standards:

* Compliance to *AS/NZS 3100:2009 Approval and test specification—General requirements for electrical equipment*
* Input voltage: between 216 V and 253 V.
* Line surge protection: tested in accordance with *IEC 61000‐4‐5:2014 Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test*
* Efficiency: at least 98% at 50% load.
* Must be able to dynamically adjust output voltage.
* Must be able to bypass supply voltages below 216V.
* Output: Must have an output voltage tolerance of + / - 3% at 230V.

## B Consistency with other schemes

There is no equivalent deemed savings method under other state schemes for Conservation Voltage Reduction.

The approach taken to CVR is simple and in line with other activities where the savings depend on the equipment parameters, rather than having to measure any site parameters such as maximum demand or annual energy consumption.

## C Benefits and Risks

**Electrical equipment benefits**

In addition to energy savings, CVR can protect other electrical equipment from damage by:

* Removing harmonics
* Line surge protection
* Increased equipment lifetime[[16]](#footnote-16)

Where a solar PV system is locked out on ‘over voltage lockout’ the CVR equipment presents the PV inverter with a constant sub lockout voltage so the PV system is not shut down. Usually PV systems are shut down during peak times so there is a benefit of continue supply by the PV system to the premise and where there is excess generation export to the grid versus drawing all the power needs from a stressed grid at peak tariff times.

**Customer benefits**

The AEMC has recently approved a rule change that requires electricity networks to adopt “cost-reflective” pricing for their services. This means that a higher proportion of energy bills will reflect the maximum demand that a customer requires (i.e. demand charges will increase in price).[[17]](#footnote-17)

In addition to saving energy, CVR equipment also reduces demand (kW and kVA) and can improve power factor. Therefore it may have additional customer energy bill benefits in the future if and when demand-based charges are brought in.

**Network benefits**

Many parts of the Victorian distribution networks are demand constrained.[[18]](#footnote-18) DNSPs are required to consider demand-side solutions to network constraints alongside building new infrastructure.[[19]](#footnote-19) Reducing customer demand can delay the need for additional network infrastructure, saving the networks from capital investment and putting downward pressure on energy prices.

**Greenhouse gas benefits**

As noted above, there are potentially over 13 million VEECs that could be created for residential CVR equipment in Victoria, which translates to 13 million tonnes of avoided CO2 emissions.

**Air pollution benefits**

Air pollution from coal-fired power stations in Victoria has significant health impacts on those people who live near the power stations.[[20]](#footnote-20) Reduced electricity consumption will also reduce these health impacts.

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10. OFGEM, *Energy Saving Trial Report for the VPhase VX1*, UK Office of Gas and Electricity Markets, June 2011, https://www.ofgem.gov.uk/ofgem-publications/58457/energy-saving-trial-report-vphase-vx1-pdf [↑](#footnote-ref-10)
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12. Victorian Government, VEET Proposed Activity Regulation Amendment Summary, Section 3, p. 3, October 2015, http://www.energyandresources.vic.gov.au/\_\_data/assets/pdf\_file/0003/1217253/VEET-Proposed-Activity-Regulation-Amendment-Summary-October-2015.pdf [↑](#footnote-ref-12)
13. Victorian Government, VEET Proposed Activity Regulation Amendment Summary, Section 3, p. 3, October 2015, http://www.energyandresources.vic.gov.au/\_\_data/assets/pdf\_file/0003/1217253/VEET-Proposed-Activity-Regulation-Amendment-Summary-October-2015.pdf [↑](#footnote-ref-13)
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