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CLIMATE SMART ENGINEERING 2021

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ENERGY Efficiency and Overvoltage:

The Hidden Electricity Thief

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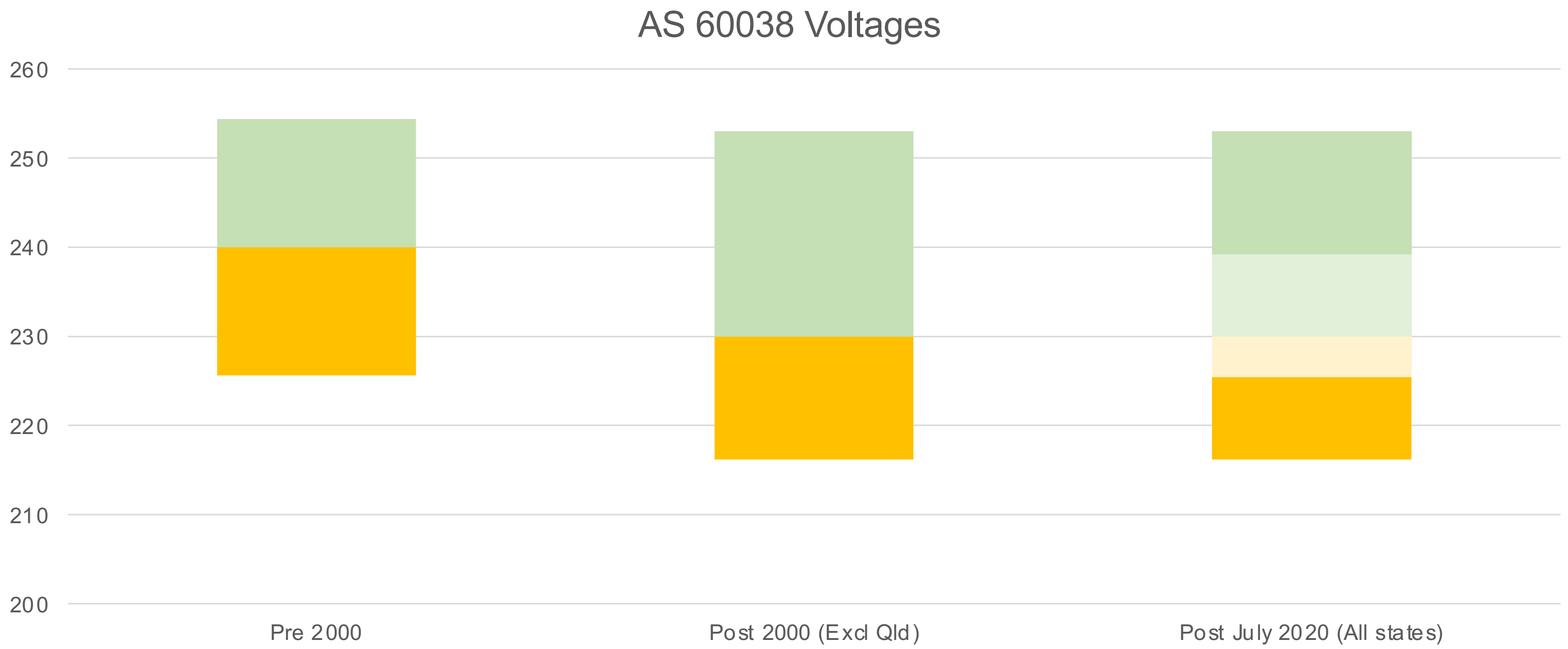
Australian Standards determine voltage levels within a set range of values



From 1 July 2020, Australian electricity networks established a ‘preferred operating range’ of 230 volts (+6% and -2%) which equates to 225.4 to 243.8 volts and is set out in AS 61000.3.100 “Steady state voltage limits in public electricity systems”.

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Voltage levels remain at or above upper limits…

Electricity is supplied at a higher than needed voltage to the vast majority of consumers:

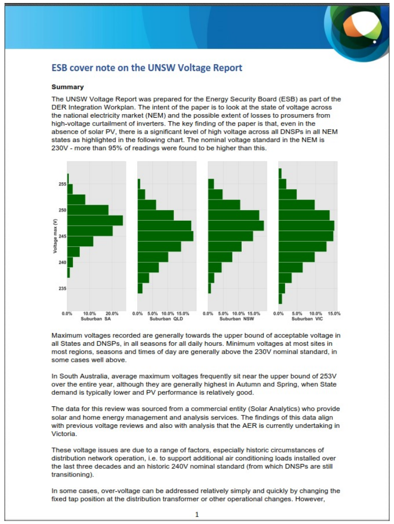
- Audits by the University of Wollongong Australian Power Quality Research Centre over more than a decade show that the average voltage delivered to consumers is well in excess of 230V, usually around 245V.
- A recent Energy Security Board sponsored study by the University of NSW found:

"Even though the nominal voltage on the grid is 230 volts, the researchers found 95 per cent of readings were higher than that level."

"The Energy Security Board, which commissioned the UNSW study, said the findings pointed to a "material level of technical non-compliance" by the networks, and a "backlog of compliance issues" that needed work."

	Queensland	Victoria	Western Australia	South Australia
Mean voltage V	249.7038	240.6472	247.5672	248.7791
Standard deviation	7.767765	5.460625	15.89345	8.25179
Q1	248.3	239.4	246.9	247.6
Q2	249.8	240.8	249	249
Q3	251.4	242.2	250.5	250.6
Max. V	258.6	253.6	257.2	258.8

From: University of Wollongong APQRC voltage survey



ESB cover note on the UNSW Voltage Report

Summary

The UNSW Voltage Report was prepared for the Energy Security Board (ESB) as part of the DER Integration Workplan. The intent of the paper is to look at the state of voltage across the national electricity market (NEM) and the possible extent of losses to prosumers from high-voltage curtailment of inverters. The key finding of the paper is that, even in the absence of solar PV, there is a significant level of high voltage across all DNSPs in all NEM states as highlighted in the following chart. The nominal voltage standard in the NEM is 230V - more than 95% of readings were found to be higher than this.

Maximum voltages recorded are generally towards the upper bound of acceptable voltage in all States and DNSPs, in all seasons for all daily hours. Minimum voltages at most sites in most regions, seasons and times of day are generally above the 230V nominal standard, in some cases well above.

In South Australia, average maximum voltages frequently sit near the upper bound of 253V over the entire year, although they are generally highest in Autumn and Spring, when State demand is typically lower and PV performance is relatively good.

The data for this review was sourced from a commercial entity (Solar Analytics) who provide solar and home energy management and analysis services. The findings of this data align with previous voltage reviews and also with analysis that the AER is currently undertaking in Victoria.

These voltage issues are due to a range of factors, especially historic circumstances of distribution network operation, i.e. to support additional air conditioning loads installed over the last three decades and an historic 240V nominal standard (from which DNSPs are still transitioning).

In some cases, over-voltage can be addressed relatively simply and quickly by changing the fixed tap position at the distribution transformer or other operational changes. However,

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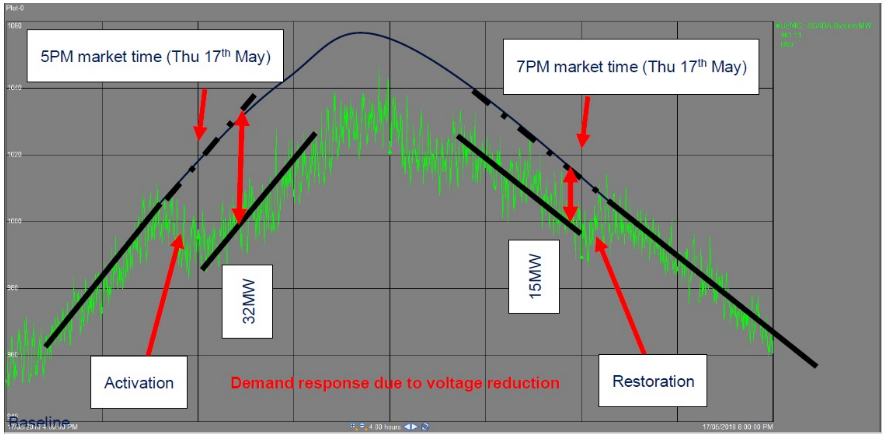
…causing wide-spread energy wastage

A number of poor outcomes result from supplying electricity at a higher than nominal voltage to the majority of consumers, most of the time:

- Power and Energy are wasted on a large scale. This was confirmed by the recent ARENA sponsored trial at United Energy, where the voltage was reduced across their network by an average of 3% during trial events, saving more than 2% in power and energy.
- Hosting capacity for renewable energy systems is severely restricted. Rooftop solar PV systems trip when the network voltages reaches 253V (+2% rise in service and consumer mains), resulting in a waste of this clean energy resource.
- Consumer Appliance lifetime is reduced. The true cost of this is poorly understood, however a recent UOW accelerated life study concluded that there is a 25% reduction in equipment life when consistently supplied at 253V vs 230V.
- Consumer bills are increased due to the reduction in efficiency of their appliances operating at increased voltage.



Demand reduction due to voltage reduction Test conducted on 17th May 2018 for a 2 hour period.
Source: United Energy Demand Response Project Performance Report - Milestone 3

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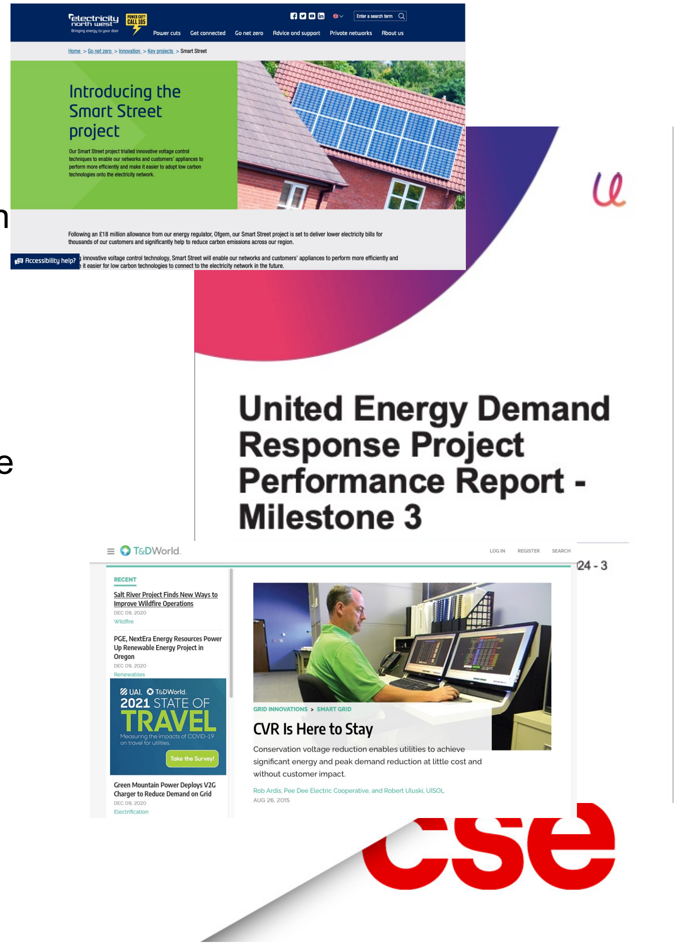
Conservation Voltage Reduction is a proven solution…

There have been many studies on CVR worldwide.

- The amount of energy saving depends on the particular load types.
- Across a wide range of loads, CVRe factors are found to be in the range of 0.6 – 1.0. A CVRe (CVR energy) factor of 1.0 means for every percentage reduction in voltage you get a 1 percent reduction in energy.
- In Australia, United Energy did a number of system wide trials from 2017 – 2019 resulting in an average CVRe factor of 0.7.
- Recent tests at Endeavour Energy have found CVR factors of up to 1.0.
- Recent extensive trials in the UK at Electricity NorthWest also resulted in average CVR factors of 1.0.
- Some Links:
- https://www.unitedenergy.com.au/wp-content/uploads/2018/07/Demand-Response-Project-Performance-Report-Milestone-3.pdf
- https://www.unitedenergy.com.au/wp-content/uploads/2018/07/Demand-Response-Project-Performance-Report-Milestone-3.pdf
- https://www.enwl.co.uk/zero-carbon/innovation/key-projects/smart-street/
- https://www.tdworld.com/grid-innovations/smart-grid/article/20965787/cvr-is-here-to-stay
- http://www.bccan.org.au/files/conservation_voltage_reduction_paper_v2.1.pdf



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…but nobody is incentivized to make the investment

Economic signals are separated

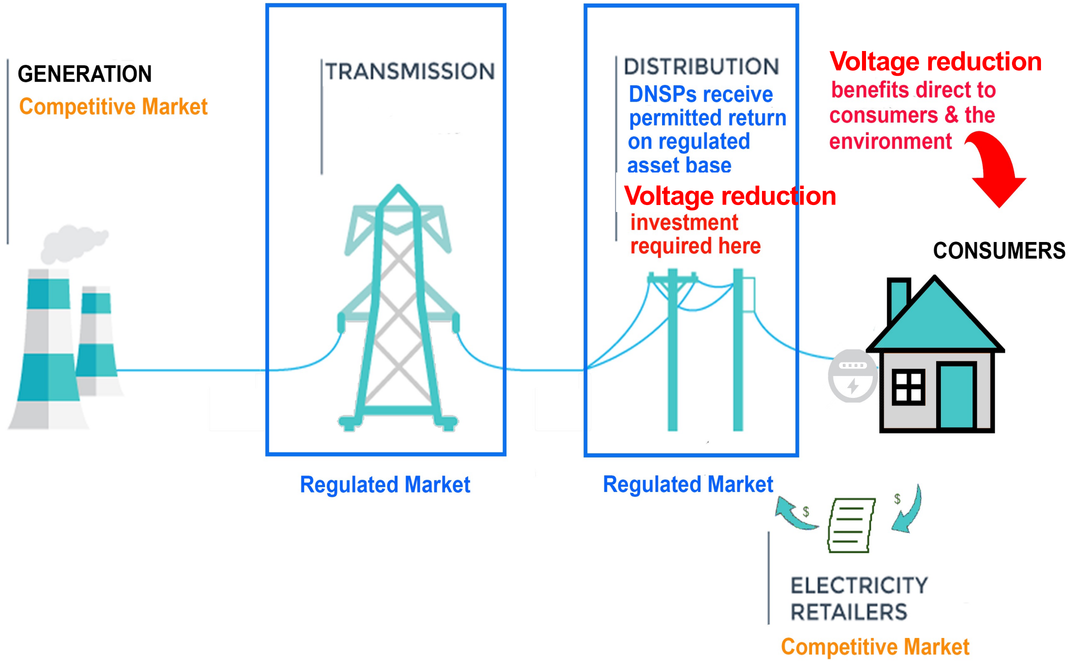
- The cost of implementing CVR resides largely with the local DNSP while the benefits derived from CVR flow largely to end use consumers. Traditionally, supporting voltage levels in weaker areas has been a capital intensive process.

Compliance enforcement is weak

- Voltage compliance enforcement by Australian technical and safety regulators is weak at best. Further, DNSP's can correctly claim that while ever they operate their networks within AS 60038 limits, they are compliant

Technical and economic regulation are separated

- The relevant regulatory bodies adhere to their respective jurisdictions – technical or economic. CVR is a technical matter which has the potential to yield significant economic benefits



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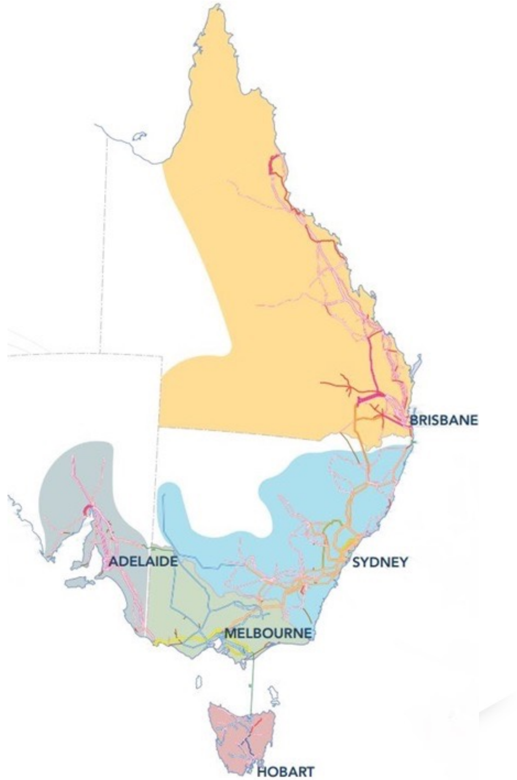
A simple change to an existing regulation could solve our voltage dilemma

- The Service Target Performance Incentive Scheme (STPIS) is a proven successful mechanism for delivering sustainable reliability benefits to customers.
- The existing STPIS scheme contains a section titled “4 Quality of supply component” on page 15. The quality of supply parameters within this section 4 state: ”4.1 Performance incentive scheme parameters: No quality of supply parameters are currently specified for inclusion in the scheme.”
- Quality of supply measures for voltage efficiency could be included within the current framework. The proposed measures should be determined through analysis and consultation.
- The AER could mandate a CVR program with a minor amendment to the existing STPIS incentive program, establishing a market for voltage management services for multiple providers.



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A 5% voltage reduction is estimated to deliver:

~5% voltage
is typically reduced across the network

~4% power saving
reduced kW across the network

~3.5% energy reduction
reduced kWh across the network

3.8 TWh
in avoided annual electricity consumption

$1.91b
in Annual benefits

01 Customer Bill Savings

- $1.06b / 3.8TWh savings per annum (NEM)*
- $108 pa per NEM Customer
- Avoided future investment in generation, transmission & distribution

02 Reduces peak demand

- Peak saving of 1000MW across the NEM*.
- Equivalent to the proposed gas fired power station

03 Reduces C02 Emissions

- Emissions saving of 3.07m tC02e (NEM) per annum
- $95m pa savings (NEM)*

04 Solar Hosting (Avoided Curtailment)

- 652 GWh recovered solar energy (NEM) per annum*
- $65m pa total consumer savings

05 Improved Customer Appliance Lifetime

- $317m savings (NEM) per annum*
- $35 pa per NEM Customer

* Figures derived primarily from AER RIN data and AEMO published data.

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Q&A

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How does CVR work?

- The simple example of an incandescent lightbulb illustrates the CVR concept. Granted, incandescent bulbs are being phased out of the electricity grid, but the example is used to illustrate the physics with an easily understood example. The lightbulb is basically a resistor. Using Ohm's law, the power consumed by the lightbulb varies with the square of the voltage. Therefore, lowering the voltage on the lightbulb will lower the energy consumed by the light. The term "Efficiency Factor" (EF) is used to identify the load-to-voltage sensitivity of an electrical device.
- For an ideal incandescent lightbulb, the EF would be 2, meaning reducing the voltage by 1% results in a 2% drop in the energy consumed by the lightbulb. In reality, incandescent lightbulbs are not perfect resistors, because the resistance of the lightbulb changes as the bulb heats up. Laboratory experiments have shown the EF for an incandescent lightbulb is actually around 1.5 because of this effect.
- Efficiency Factors are important to understand the impact that reduced voltage has on certain devices. In the commercial arena, induction motors are known to operate as constant power demand loads when operating at their full power. This would imply that loads involving induction motors have a low or even negative EF. Interestingly however, those same induction motors exhibit different load characteristics when they are operating at less than their maximum load [11], exhibiting favourable EF's under lightly loaded conditions.
- Most electrical equipment exhibits a positive load-to-voltage sensitivity (EF). Most equipment has an EF of at least 50% and will consume less energy when lowering the voltage. Some equipment exhibits near-zero load-to-voltage sensitivity. These devices are mostly power electronics-based with switched power supplies that automatically adjust the voltage delivered to the power supplies' internal components.
- The significant diversity of equipment connected within any individual premise or business, coupled to the large volume of connected equipment to any one low voltage feeder network results in aggregated EF's which are consistently favourable to connected customers [5], [6].

- [11] David, Jason R.; Elphick, Sean T.; and Crawford, Matthew, "Cause and effect of overvoltage on the LV network" (2017). Faculty of Engineering and Information Sciences - Papers: Part B. 1700. https://ro.uow.edu.au/eispapers1/1700
- [5] Electricity North West Smart Street Voltage and Configuration Optimisation, 10 April 2018 https://www.enwl.co.uk/globalassets/innovation/smart-street/smart-street-key-docs/final-hv-and-lv-voltage-and-configuration-optimisation-study.pdf
- [6] United Energy Demand Response Project Performance Report - Milestone 7 https://arena.gov.au/assets/2020/09/united-energy-demand-response-project-demand-response-report-7.pdf

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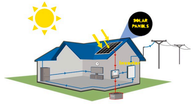
Now – force feeding power to many, some still not getting enough

Sending voltage too high 245 to 252 volts

VOLTAGE TOO HIGH

Cost to consumers too high

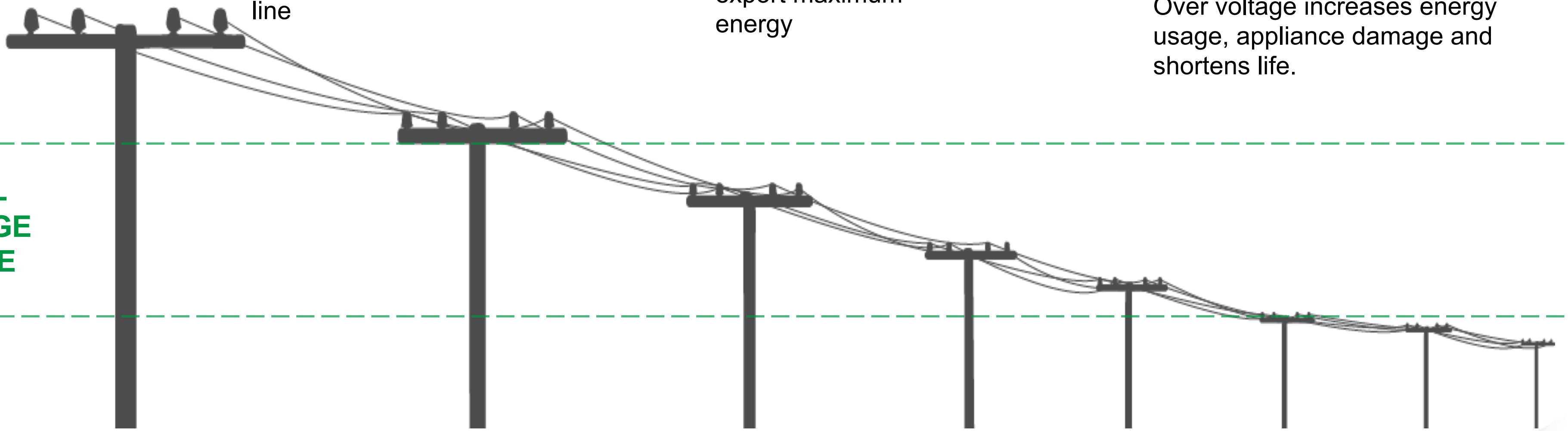
Increased CO_2 emissions needed
to force more power down the line



Solar **cannot** export maximum energy

Over voltage increases energy usage, appliance damage and shortens life.

IDEAL VOLTAGE RANGE



VOLTAGE TOO LOW

Voltage too low below 216 volts

Under voltage may cause equipment to malfunction.

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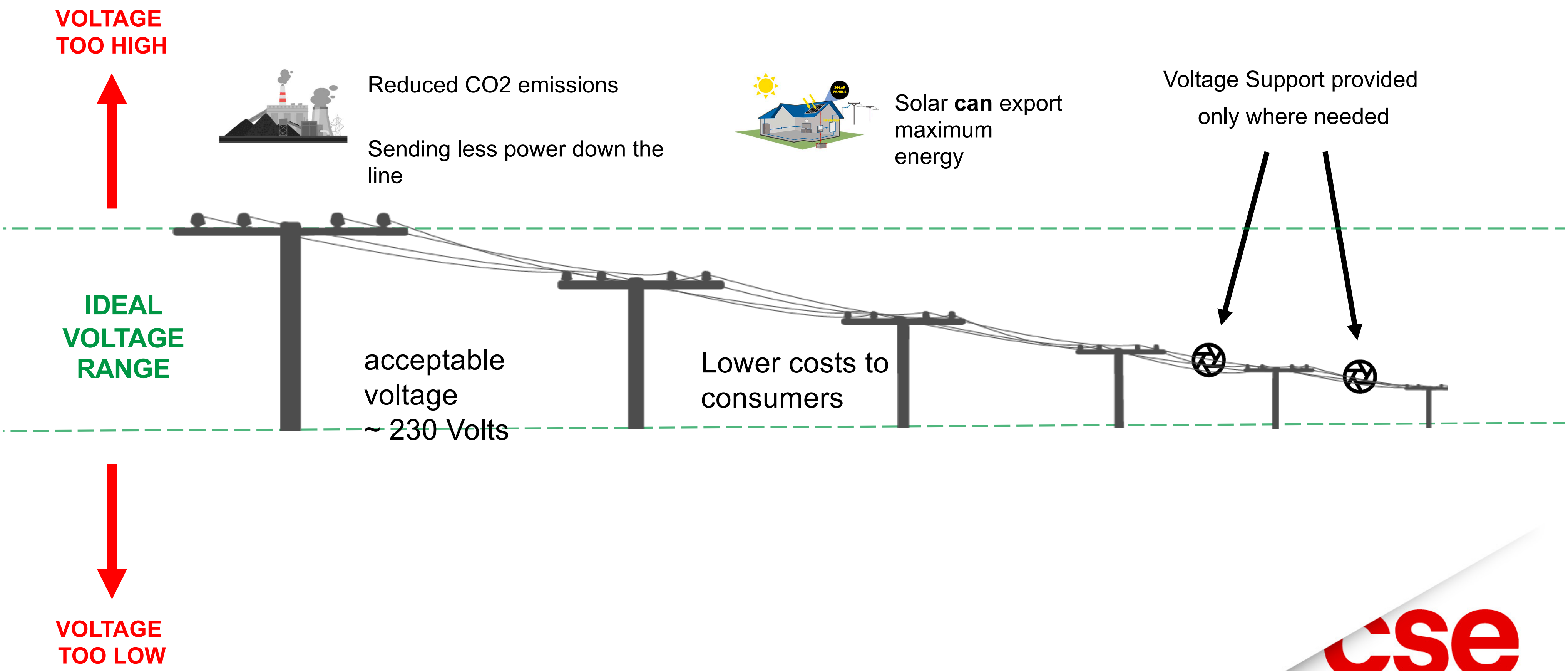
CVR – sending only the power needed - cheaper, more efficient and fairer to all



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A 5% voltage reduction is estimated to deliver:

Cash savings to Energy Consumers

Average savings of at least $108 per household and SME, annual and ongoing. Totalling $1.06 billion per annum across the National Electricity Market.

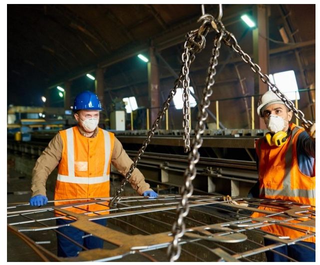
Greater Energy Security

NEM demand for energy reduced by 1000 MW thus reducing the need for generation. Increased security in the face of coal fired generation closures.

Reduced Carbon Emissions

Reduce Australia's CO_2 emissions by over 3 million tonnes per year.

Job Creation



Create approximately 1,000 new jobs through circular economy outcomes in manufacturing and increased consumer spending power from energy savings.