Decision regulatory impact statement

Queensland's statutory voltage limits

27 September 2017

million solar rooftops

Queensland Government

This publication has been compiled by Energy Industry Policy, Department of Energy and Water Supply

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Executive summary

The uptake of embedded solar generation by Queenslanders is one of the highest in the world and this growth is expected to continue with supportive Queensland Government policies and targets aimed at increasing solar photovoltaic (PV) and renewable energy deployment across the state. This prompted the Department of Energy and Water Supply (DEWS) to engage a consultant to examine and provide technical advice about approaches to balancing greater uptake of solar PV and renewables with the safe and reliable operation of the electricity network, including the review of Queensland's network voltage requirements.

The specification of power supply voltage by legislation is common in Australia, and is intended to ensure safe and efficient operation of electrical appliances. It is common for legislation to place maximum and minimum limits on the allowed power supply voltage. In Queensland, Part 2 of the *Electricity Regulation (Qld) 2006* sets the minimum or 'floor' at 225.6 volts and the maximum 'ceiling' at 254.4 volts. This represents a nominal voltage of 240 volts +/- 6 per cent.

Evidence indicates that this regulated 'floor' is too high for modern electrical networks as, in many instances, it restricts the distribution network service providers' (distributors) ability to support renewable generation and address voltage rise more effectively through the simple and cost-effective mechanism of reducing the power supply voltage. Without widespread access to this option, distributors will rely on expensive capital investment in network capacity and technical control systems, or to place restrictions on the connection to the network and operational flexibility of customer technology such as energy storage and embedded PV generation.

To address these issues, the electricity supply voltage range set under existing legislation could be reduced by around 10 volts to the international standard of 230 volts +10 per cent / -6 per cent (the 'international standard') without risk to the safe operation of electrical appliances. The international standard is reflected in Australian Standards (AS) 60038:2012 and 61000.3.100 both of which form the basis of voltage regulation in most other Australian states and many countries.

This Decision Regulatory Impact Statement (RIS) considers five options:

- **Option 1:** Retain existing voltage requirements (base case).
- **Option 2:** Adopt AS60038 (also known as the '230-volt standard') with a one-year transitional period, and full compliance with AS61000.300.1 in seven years (broadly in line with distributors standard operation and maintenance (O&M) schedules).
- **Option 3:** Move to 230V standard (AS60038) over a one-year transitional period and full compliance with AS61000.300.1 over three years (distributors to develop and implement a dedicated program to fast-track implementation in conjunction with O&M activities).
- **Option 4:** Move to a wider voltage range than specified in the national standard (e.g. 230 V ± 10 per cent).
- **Option 5:** Remove Queensland power supply voltage requirements and use market forces or other legislation to deliver safe and effective outcomes (non-regulatory approach).

The RIS discounts Option 4 as it is inconsistent with voltage limits in other jurisdictions and does not reflect current international best practice. Similarly, Option 5 is discounted because there is insufficient empowerment of customers and market competitive forces to ensure voltage standards are maintained. As such, the impact of these options on affected stakeholders are not considered in detail in this RIS.

Impact assessment

Draft impact assessment

Table 1 summarises the costs and benefits of the remaining Options 2 and 3, relative to Option 1 (the base case). Both Options 2 and 3 ultimately result in best practice voltage management and benefit the integration of renewable energy into the Queensland electricity grid. The key difference is that Option 3 is implemented faster than Option 2 and as such allows greater amounts of renewable and embedded generation to be integrated earlier than Option 2. This is important as it brings forward benefits such as increased network solar hosting capacity and more flexible connection requirements for customers in time to support government's target of 3000 megawatts of installed solar capacity by 2020. It helps the state prepare early for our renewable energy future. As a flow on effect, Option 3 also brings forward environmental and solar industry benefits compared with Option 2.

An economic cost benefit analysis (CBA) of Options 2 and 3 (relative to the Option 1 base case) indicates both options will bring financial benefits to electricity consumers in Queensland through energy efficiency savings, noting that energy efficiency outcomes may be variable and a sensitivity analysis has been conducted to test this variability. Energy efficiency benefits are captured earlier and are therefore higher under Option 3. The risk to customers of appliance failure/damage from high voltage also reduces more quickly under Option 3, as does the risk of household solar PV automatically disconnecting from the network to protect itself in times of high voltage.

The CBA also indicates reduced operating costs for distributors through greater access to lower-cost network solutions to address voltage rise. These benefits are offset by cost impacts on electricity retailers and generators. The high-level impacts of Options 2 and 3 (relative to the base case) are summarised in Table 1.

Table 1 – Summary of financial impacts (draft impact assessment)

Stakeholder	Option 1 (base case)	Option 2	Option 3
Queensland Government	• Regulatory requirements that create barriers to the government's renewable energy policy objectives. • Divergence from international best practice in the operation of government assets.	• Potential flow-on effects from government-owned retailer and generators. • Potential to either benefit or add cost to the Community Service Obligation payment.	• Supports government's 2020 solar targets and investment potential under the RET. • Potential flow on effects from government-owned retailer and generators.

			- Potential to either benefit or add cost to the Community Service Obligation payment.
Distributors (Energex and Ergon Energy)	- $109 million in operating costs to address voltage rise in the current regulatory period. - $2.2 million per year to address customer high voltage complaints. - $60,000 per year in insurance claims for appliance damage associated with voltage rise.	- $58 million net present value (NPV) benefit as a result of reduced expenditure on network augmentation and customer complaints.	- $52 million NPV benefit as a result of reduced expenditure on network augmentation and customer complaints.
Retailers	- Business as usual.	- $31 million NPV loss as a result of reduced electricity demand.	- $39 million NPV loss as a result of reduced electricity demand.
Generators	- Business as usual.	- $19 million NPV loss as a result of reduced electricity demand.	- $23 million NPV loss as a result of reduced electricity demand.
Customers (end users)	- Risk of voltage rise causing appliance failure/damage. - $4 million per year in reduced appliance life. - Strict technical assessment thresholds for solar PV grid connection in the Ergon Energy distribution area. - Continued restriction of energy feed-in for many embedded generators.	- $198 million NPV benefit as a result of increased solar uptake and improved energy efficiency.	- $257 million NPV benefit as a result of increased solar uptake and improved energy efficiency.

Solar Industry	- A rapid slow-down in the uptake of rooftop solar. - Network capability to absorb energy feed-in within regulated limits will saturate.	- $9 million NPV benefit as a result of increased solar uptake.	- $9 million NPV benefit as a result of increased solar uptake.
Environmental	- No impact.	- 1.7 million (tCO2-e) over 10 years as a result of reduced electricity consumption. - 40MW of additional solar capacity by 2020.	- 2 million (tCO2-e) over 10 years as a result of reduced electricity consumption. - 40MW of additional solar capacity by 2020.
Total NPV benefit	**N/A**	**$215 million**	**$256 million**

Results of stakeholder consultation

DEWS released a Consultation RIS for public feedback on 16 March 2017 and received submissions from 116 individuals and organisations in response, noting that consumer group solar citizens forwarded 111 submissions on behalf of interested individuals (collected via its website). Other stakeholders that made a submission include AGL, Origin Energy, Master Electricians Australia, Dr. Dianna O’Connor and Energy Queensland. All submissions supported adoption of AS60038 and AS61000.300.1. A summary of stakeholder submissions and the Queensland Government response is in Table 2.

Table 2 – Stakeholder submission summary

Stakeholder	Support/Preferred option	Submission points	Government Response	Changes made to the RIS
AGL	Support Option 3.	Faster transition and compliance process will most effectively and efficiently support the uptake of distributed energy resources technologies.	Noted.	No change to the RIS.
		The RIS was not clear on the following issues: • the up-front costs to networks to implement Option 3 • whether networks would forgo other business priorities to meet the Option 3 timeline and its associated implementation costs.	The Decision RIS considers the issue of accelerated roll-out costs for networks to implement Option 3 in section 4.5.2.1.	No change to the RIS. See section 4.5.2.1 of the RIS for discussion.
		Any reduction in voltage appears to only solve a short-term problem that is addressing voltage rise and power quality. Networks must be directed to consider how to best improve, at least cost, their grid systems for increased bi-directional energy flows over the medium to long term. This consideration should include the potential for competitively provided non-network solutions (such as energy storage systems) that have the capability to efficiently support long-term grid voltage management issues.	Noted. Consideration of non-network solutions such as storage to support grid voltage are outside the scope of this RIS analysis. However, it should be noted that networks are already required to consider a broad range of solutions to support growth and reduce costs. Such solutions include demand management, load control and will increasingly consider storage opportunities.	No change to the RIS.

Stakeholder	Support/Preferred option	Submission points	Government Response	Changes made to the RIS
		Irrespective of the final option selected by the Queensland Government, a robust implementation plan and ongoing consultation with industry stakeholders will be necessary to ensure the forecast benefits are delivered to Queensland consumers.	Performance monitoring of the proposed recommendation is set out in section 8.3 of the Decision RIS.	No change to the RIS.
		Greater transparency at the feeder and transformer level on the distribution networks could further enhance solar PV penetration in Queensland. For example, the development of a community PV tool could be used to identify available connection capacity.	Noted. Transparency of network information is beyond the scope of this analysis.	No change to the RIS.
Energy Queensland	Support Option 2 or 3.	Global trends in solar, batteries and electric vehicles (EV's) continue to indicate a rapidly increasing pace of change which would favour the earliest possible deployment of the new standard. Energex and Ergon Energy support both Options 2 and 3, and will work with the DEWS to effectively transition to the 230V standard and deliver benefits to customers.	Noted.	No change to the RIS.

<table>
<tr><th>Stakeholder</th><th>Support/Preferred option</th><th>Submission points</th><th>Government Response</th><th>Changes made to the RIS</th></tr>
<tr><td></td><td></td><td>Energex and Ergon Energy proposed the following allowable limits relating to higher voltage ranges of 11kV and above:
<table>
<tr><th>Voltage Level in kV</th><th>Steady State Limits</th></tr>
<tr><td><1.0</td><td>+ 10%, -6 %</td></tr>
<tr><td>1-33</td><td>± 6%</td></tr>
<tr><td>≥ 66</td><td>± 10%</td></tr>
</table></td><td>Noted. Allowable voltage range and steady state limits will align with those inherent in AS60038 and AS61000.3.100.</td><td>No change to the RIS.</td></tr>
<tr><td></td><td></td><td>Table 4 of the Consultation RIS incorrectly totals the customer complaint benefits for distributors and solar self-use benefits for new solar customers.</td><td>Noted. Corrected in the Decision RIS.</td><td>Table 8 (Table 4 in the Consultation RIS) updated accordingly.</td></tr>
<tr><td>**Master Electricians Australia**</td><td>Support – preferred option not specified.</td><td>Support a drop in voltage levels to align Queensland voltage arrangements with the rest of Australia and adhere to international best practice.
Lowering voltage levels in Queensland may also improve the energy efficiency of appliances. This would in turn reduce consumer electricity bills and have a positive impact on the environment.</td><td>Noted.</td><td>No change to the RIS.</td></tr>
</table>

Stakeholder	Support/Preferred option	Submission points	Government Response	Changes made to the RIS
Submissions forwarded on behalf of 111 individuals by Solar Citizens.	Support Option 3.	Solar Citizens forwarded submissions to DEWS on behalf of 111 interested individuals. All submissions indicated support for the proposal with many pointing to the benefits highlighted in the Consultation RIS, namely: • Increased ability of the network to absorb higher solar uptake especially in regional Queensland, facilitating an estimated 40MW of additional solar installed by 2020; • Fixing the problem of voltage rise and associated appliance failure; • Saving $257 million for energy consumers; • Improving energy efficiency; • A reduction of 2 million tonnes of carbon over ten years through reduced electricity consumption; • Speeding up the process for solar connections.	Noted. The benefits highlighted in these submissions largely restate those discussed in the Consultation RIS.	No change to the RIS.
Dr. Diana O'Connor	Support – preferred option not specified.	The advantages sound excellent on all counts.	Noted.	No change to the RIS.

Stakeholder	Support/Preferred option	Submission points	Government Response	Changes made to the RIS
Origin Energy	Support in principle – preferred option not specified.	The differences in the upper and lower limits under the two standards (240V vs 230V) will mean a large number of solar inverters currently installed in Queensland may be technically non-compliant under the proposed new 230 volt standard. If the grid voltage is outside the inverter's set voltage operating range, it will error.	The Decision RIS considers the issue of legacy inverters in section 4.4.5.2.	See section 4.4.5.2 of the RIS for discussion.
		The implementation costs and the implications for the existing inverter voltage settings comes down to how the networks plan to operate the grid and enforce compliance with the proposed standard. It is more likely to be an issue in regional Queensland where the grid operates around 250 volts today and inverters are also required to add a 2 per cent voltage rise.	The Decision RIS considers the issue of additional costs to customers as a result of legacy inverters in section 4.4.5.2.	See section 4.4.5.2 of the RIS for discussion.
		The cost benefit analysis to assess the benefits of lowering the voltage standard must be consistent with the Australian Energy Regulator's incentive schemes. Specifically, savings from lowering the voltage standard cannot be treated in isolation; they must assess the impact of what they do with these savings under the conditions set by the regulatory framework. If these savings are	Noted. The Decision RIS clarifies the treatment of identified savings from reduced network augmentation expenditure in section 4.4.3.1 of the RIS under the heading 'Augmentation expenditure savings'.	See section 4.4.3.1 of the RIS for discussion.

Stakeholder	Support/Preferred option	Submission points	Government Response	Changes made to the RIS
		reallocated to other projects and do not result in net financial benefit to customers, then that is the value of the benefit (or additional cost) that must be used for the purposes of the cost benefit analysis.		
		The RIS does not appear to recognise that the reduction in the voltage will increase network losses. Origin believes the cost benefit analysis should be adjusted to recognise these losses and estimates included within the NPV calculations.	Noted. The Decision RIS clarifies the treatment of network losses in section 4.2 of the Decision RIS.	See section 4.2 of the RIS for discussion.

Conclusion

DEWS has considered all submissions made in response to the Consultation RIS and clarifies a number of issues raised, in the analysis. However, the figures in the CBA and conclusion of the RIS remain unchanged, specifically:

This Decision RIS recommends that resetting the existing voltage settings across the Queensland electricity distribution network over 3 years (Option 3) to levels in line with international best practice will better support government policy objectives and provide a greater net benefit overall. This reset can be undertaken with no net increased cost to distributors (funded through resultant network savings) and therefore will not add to costs for energy consumers.

1. Background information

1.1. Connection voltage explained

The term ‘voltage’, measured in ‘volts’, refers to the electromotive force present in a supply of electrical energy. An analogy is the pressure of water from a tap – the higher the pressure, the greater the force present. Similarly, the greater the drain on the supply, known as demand, the more the pressure falls at a given supply point. Power supply behaves a similar way; the greater the demand at any point in time, the more the voltage falls.

The measured voltage of the mains power supply at premises varies across a permitted range because of changing energy demand at the premises and other points of electrical demand on the distribution network. Generally, voltage will be lower during times of high network demand. Appliances and electrical equipment are designed to operate efficiently within a range of voltage. In Australia, that range is typically 205 – 253 volts. Different types of equipment are more tolerant of variations in voltage.

It is a requirement for distributors to design and operate the electricity network so that the variation in voltage remains within limits under legislation. Distributors manage this through a limit on the number of and capacity of connections to individual segments of the network and the installation of automatic control equipment at bulk supply points.

1.2. History of voltage standards

1.2.1 Early voltage standards

In the early days of the electricity industry in Australia and in similar networks around the world (circa 1926–1980), local state-by-state legislation set the allowable voltage range to be observed by the electricity distributors to ensure the safe and efficient operation of appliances and related electrical equipment.

Australian Standard AS2926:1987, which commenced life as standard C1 in 1926, was adopted widely. This standard centred on 240 volts with a range of ± 6 per cent. Western Australia adopted a 250-volt standard reflecting a concern for excessive voltage drop over long rural power lines.

Most appliances, including motors, refrigerators and lights were designed and/or manufactured in Australia to meet these standards. ‘240 volts’ became a common descriptor for power supply. Local appliance and equipment manufacturers supplied the local market with ‘240-volt’ equipment.

1.2.2 The evolution of common international voltage standards

In 1983, the International Electrotechnical Commission IEC) proposed a common international voltage standard in response to the growing international appliance market, allowing for the specification of consumer electrical equipment for use in many countries. The general requirement currently adopted in Australia of 240 volts ± 6% was merged with the wider international 220-volt requirements, producing a standard known as IEC 60038, which specified a nominal voltage of 230 volts with a permitted range of +10 per cent (max 253 volts) to -6 per cent (216 volts).

From 2000, when state and international trade in electrical appliances was commonplace and modern electrical equipment was generally more tolerant of a wider range in supply voltage, jurisdictions in Australia started to adopt the international standard. The last states to adopt the national standard were South Australia around 2000 and New South Wales around 2012.

1.2.2.1 Queensland voltage standard vs the uniform national standard

Current Queensland regulation reflects what is commonly known as *‘the 240-volt standard’,* where the supply voltage can range between 223 and 254 volts (12 per cent).

Electricity Regulation (QLD) 2006

The allowable range of voltage supply to electricity customers is regulated in Queensland under Part 2 of the *Electricity Regulation (Qld) 2006.*

Under this part, s9 states:

> *"A person who designs, builds, maintains or operates an electric line or works must ensure the provisions of this part relevant to the line or works are complied with. Maximum penalty—20 penalty units."*

The predominant sections of this part in relation to electricity supply voltage are:

s11 (2): *The standard voltage for electricity supplied at low voltage from a 3-phase system must be:*

- *(a) between a phase conductor and the neutral conductor—**240V**; and*
- *(b) between 2 phase conductors—415V.*

s11(3): *The standard voltage for electricity supplied at low voltage from a single-phase system must be:*

- *(c) between a phase conductor and the neutral conductor—**240V**; or*
- *(d) between the phase conductors—480V*

s12: (Permits the voltage of supply to a high voltage customer to be set by negotiation)

s13: Changes of voltage at customer's consumers' terminals

- *(1) Supply of electricity by an electricity entity to a customer must be maintained at the standard voltage mentioned in section 11 or 12.*
- *(2) Electricity is taken to be maintained at the standard voltage if the voltage at a customer's consumers' terminals is within the allowable margin for the voltage.*
- *(3) The allowable margin is—*
  - *a. **for low voltage—6% more or less than the standard voltage**; or*
  - *b. for high voltage of 22,000V or less—5% more or less than the standard voltage; or*
  - *c. for high voltage more than 22,000V—the margin*

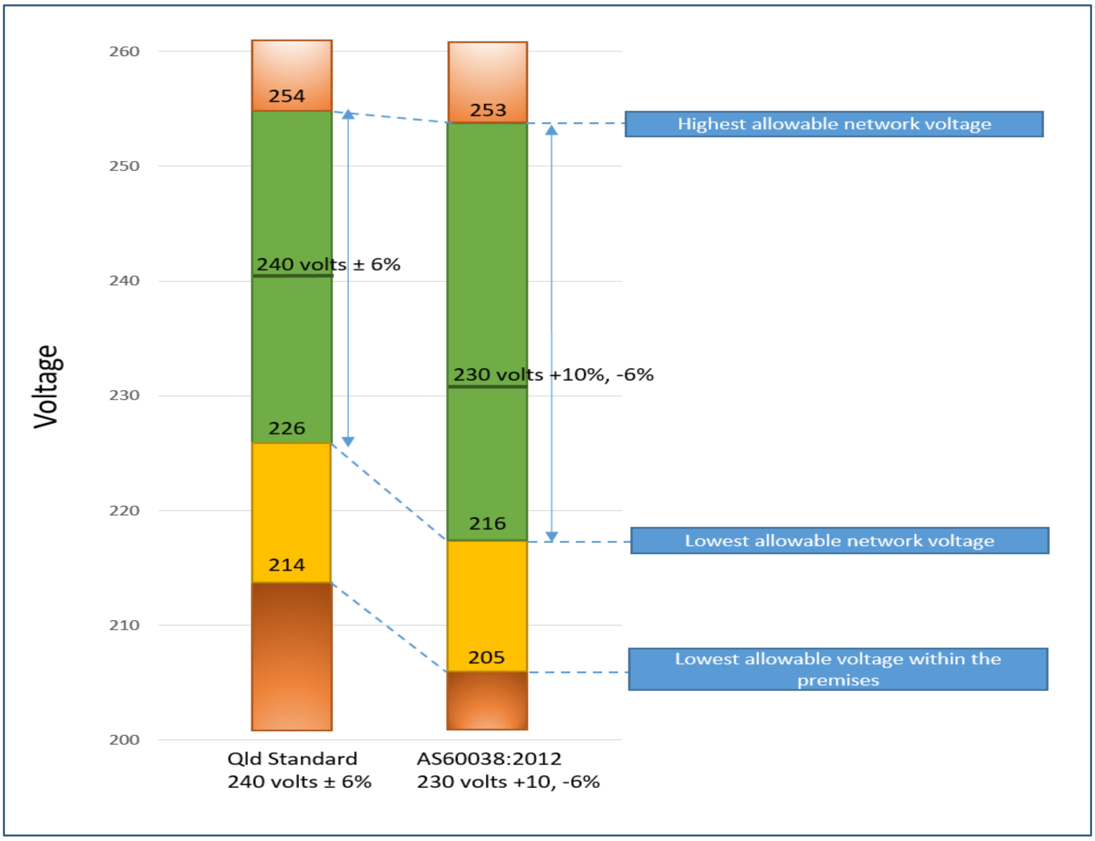
A note on voltages specified in the regulation (refer Table 1 of AS60038 – 2012)

In s11(2), the value of 415 volts is the three-phase equivalent of 240 volts, being the single phase value multiplied by the square root of 3. In the national standard, the voltage between any two phase conductors is 400 volts, using the same formula.

For s11(3), the voltage in a single-phase three-wire system becomes 260 volts, being twice the single-phase value.

The uniform national standard AS60038:2012, known as 'the 230-volt standard' permits a wider 16 per cent range of voltage, with a maximum allowable voltage of 253 volts and a minimum allowable voltage of 213 volts (Figure 1).

Figure 1 –Voltage ranges of the Queensland and IEC standards (Source: TCA)



Points of difference between the current legislated standard and the national standard include:

1. The allowable maximum network voltage under the national standard is 1 volt (0.4 per cent) lower than the current level.
2. The IEC standard permits a lower minimum voltage on the grid of 213 volts, resulting in the minimum voltage of supply at times of maximum demand the premises of 205 volts.
3. The allowable operating range for the network is 37 volts, significantly more than the 28 volts currently permitted under Queensland regulation (See ‘the tidal range’ analogy below).
4. Both standards permit 5 per cent voltage drop (approx. 11 volts) within the premises (the yellow bar in the Figure 1 above), consistent with Australian Wiring Rules.
5. The current Queensland requirements ‘fits within’ the IEC standard for the entire voltage range, except for the top ‘1 volt’.

The ‘Tidal Range’ Analogy

Low voltage network design relies on an assumption of the electricity demand placed on the network by each customer along the line. This estimate, known collectively as ‘After Diversity Maximum Demand’ or ADMD, leads to a calculation of the highest voltage (at low load time) and lowest voltage (at times of high load) seen at the customer’s connection point.

Design principles for many years consider a customer’s load to vary from a low of 0.5 kilowatts in the early morning hours to a maximum of around 4.5 kilowatts at dinner time. This defines an analogous ‘tidal range’ for about 4 kilowatts in demand from highest to lowest.

Low voltage networks are designed and operated on the understanding that this 4 kilowatt ‘tidal range’ can exist within the current 12% (± 6%) allowable range of connection point voltage.

With many homes now hosting embedded generation however, the power interchange at some connection points within the low voltage network can vary from a peak demand of, say, 4 kilowatts, to a low of *minus 4 kilowatts* (i.e. feed-in generation). In this case, the ‘tidal range’ of power flow at the connection is now up to 8 kilowatts.

Given the roughly linear relationship between the voltage at the connection point and the energy demand, a design voltage range of ± 6%, whilst adequate for areas with no embedded generation, is insufficient to reasonably cater for the doubling of the ‘tidal range’ seen at, in places, more that 30% of the connected premises in the street feeding power into the street.

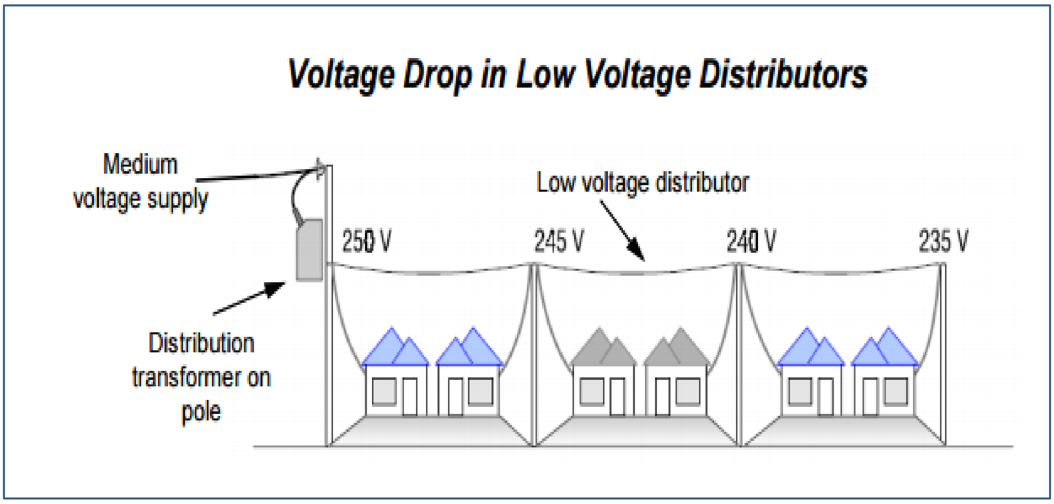
A solution that allows a wider ‘tidal range’, such as the 16% range under the IEC voltage standard is needed. The alternative is significant network augmentation (new conductors, new transformers).

1.2.3 Network operating voltage

A fundamental concept with the delivery of electricity is that the voltage along a length of power line will rise or fall as a function of the magnitude and direction of the power flowing through it.

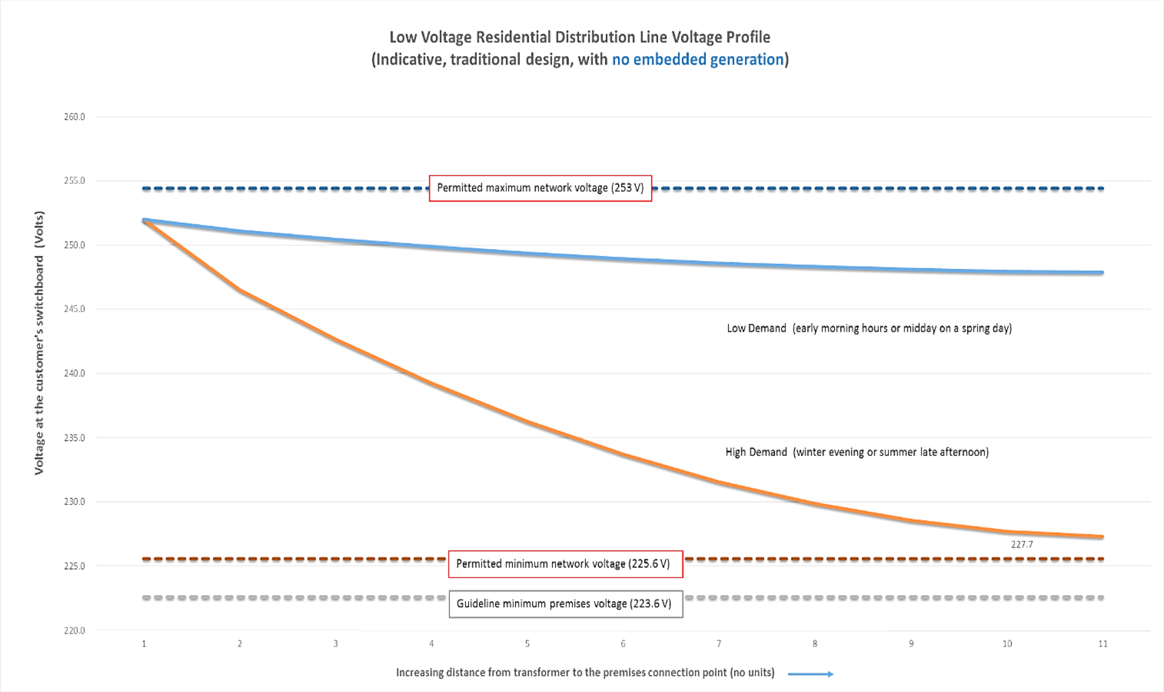
There are over 150,000 segments of low voltage distribution line in Queensland, each comprising a distribution transformer and sections of low voltage line (overhead or underground) that supply between one and one hundred premises. Power supply networks have traditionally been set to operate at the ‘top of the allowable voltage range’. For distribution networks, where one-way power flow has been the norm, operating a power distribution network with the source (transformer) set near the upper limit of the permitted voltage range provides assurance that the voltage at connection points (premises) towards the end of the local line do not dip below the minimum permitted level during times of peak demand. Figure 2 demonstrates the concept of voltage drop on low voltage networks.

Figure 2 – Voltage drop on low voltage networks



A greater amount of customer load can be supplied through longer lines before the voltage at the far end of the line falls to a level close to the prescribed low voltage limit of 226 volts (240 – 6%)[1]. As power flow has until recently been 'one-way', the design is such that the voltage is set high enough so that will not fall below the permitted minimum at times of maximum network demand, such as a cold July night or full-load at commercial premises. As is often the case now with significant distributed embedded generation, power can flow back to the grid, forcing the voltage up above the normal setting, leading to excess voltage at times of low demand and high feed-in. Figure 3 shows a typical voltage profile with no embedded generation.

Figure 3 – A typical voltage profile on a local low voltage line, with no embedded generation. (Source: TCA)



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[1] Barr, R, Wong P and Baitch, A, New Concepts for Steady State Voltage Standards, 2012.

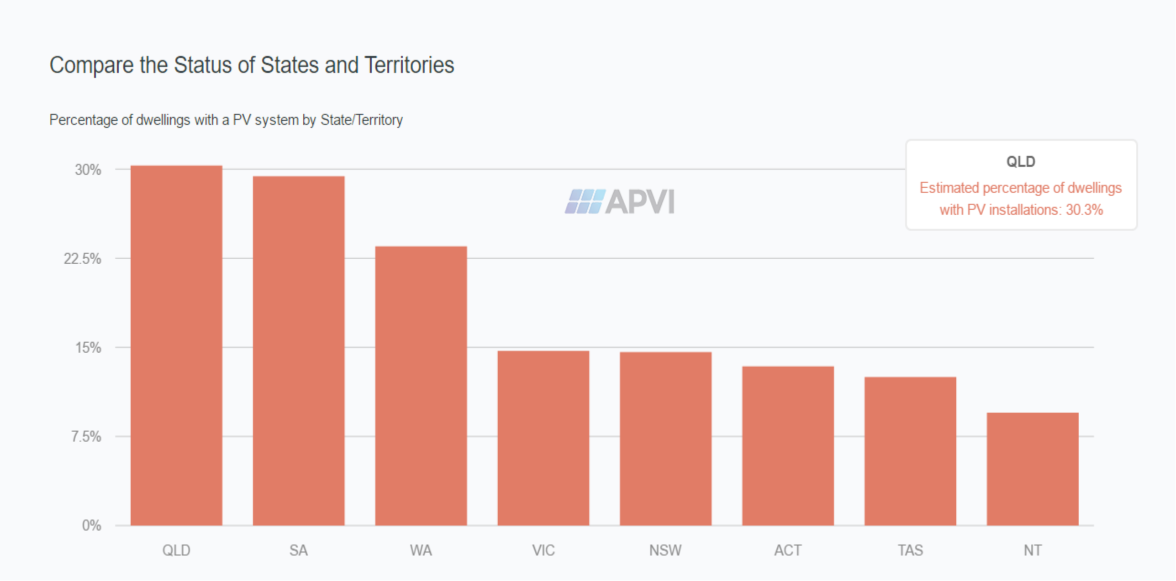
1.2.4 Growth in solar PV in Queensland

Queenslanders have embraced embedded generation, in particular rooftop solar PV, to the point where in the past Queensland has attained the status of having the highest penetration of embedded generation in the world.

Installation rates remain strong with data from the Clean Energy Regulator indicating that 21 per cent (over 1 in 5) of the PV systems in Queensland have been installed since January 2015, well after the shutdown of the premium feed-in tariff in 2012. Those systems installed in the past two years account for almost 30 per cent of the installed solar PV capacity.

The average size PV system installed in Queensland continues to climb to over 5.3 kilowatts reflecting the trend for larger inverters and the growth in the number of small commercial (non-feed-in tariff (FiT)) systems. The Australian PV Institute data from June 2016 in Figure 4, notes 30.1 per cent of dwellings in Queensland have PV.

Figure 4 – Penetration of solar PV in Queensland (Source: APVI)



Earlier in 2016, the Australian Energy Market Operator commissioned the Jacobs Group to consider the future growth of embedded generation and new customer technologies. The report, published in June 2016, noted strong growth of PV and integrated PV and storage system uptake in the commercial sector, after a decline in growth in installations in the residential segment expected after 2032[2].

The total capacity of systems in Queensland at the end of forecast period is 6,552 megawatts (MW), the highest of all states (Figure 5).

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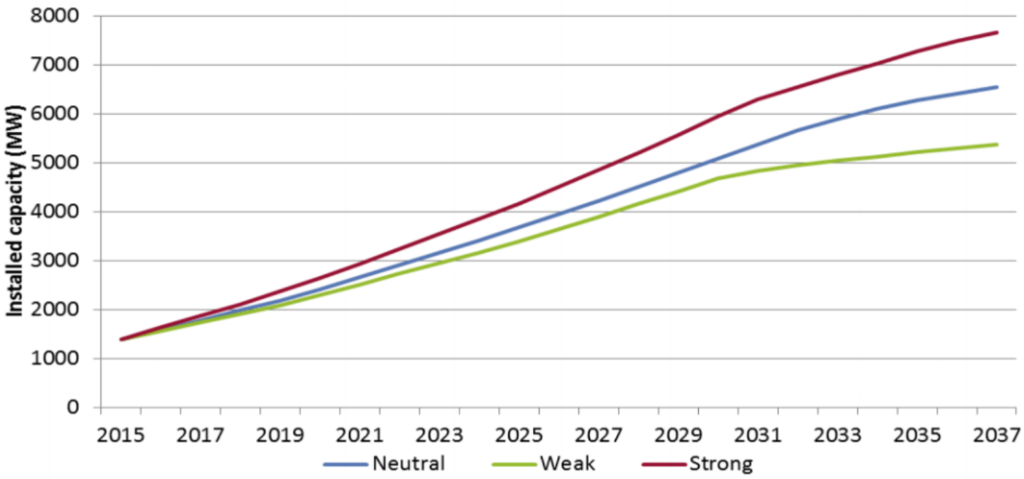
[2] Jacobs Group (Australia), Projections of uptake of small-scale solar (AEMO), 2016.

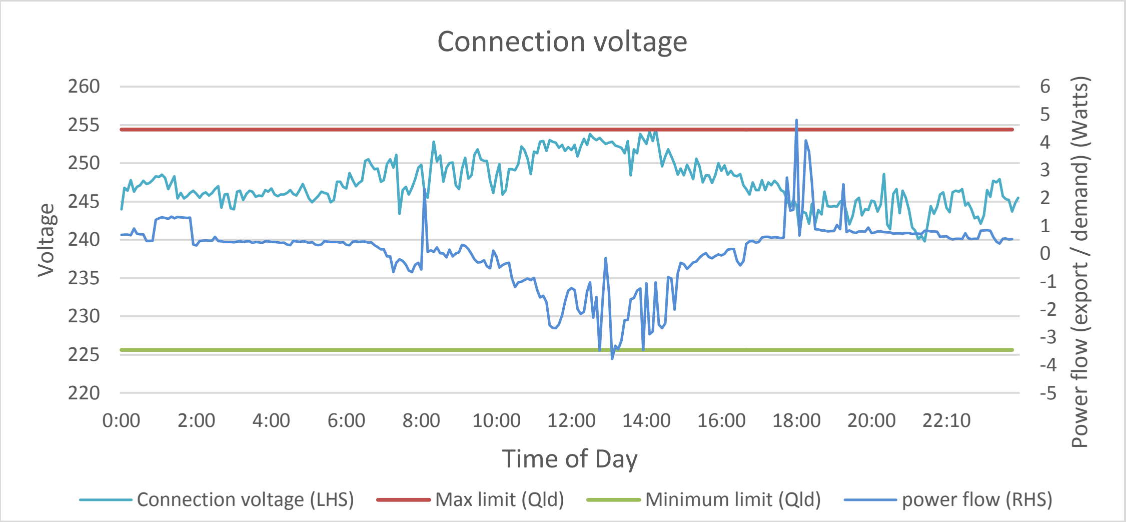
Figure 5 – Queensland rooftop PV and battery storage forecasts (Source: Jacobs / AEMO)



1.3. The impact of embedded generation on supply voltage

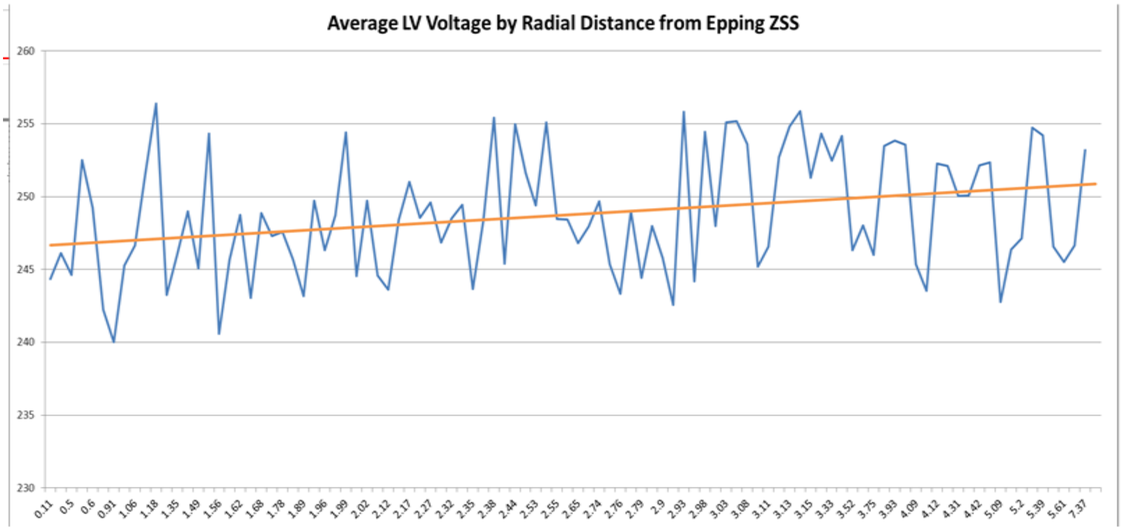
Figure 6 shows a typical voltage profile for a connection to residential premises in Queensland. The impact of voltage rise around midday because of embedded PV generation export is evident, as is voltage fall coincident with high energy demand in the early evening. Note, the voltage is always in the upper half of the allowable range reflecting the practice to 'run the voltage high' to reduce the risk of low voltage at times of extreme energy demand.

Figure 6 – Typical connection voltage profile, residential premises with solar PV (Source: TCA)



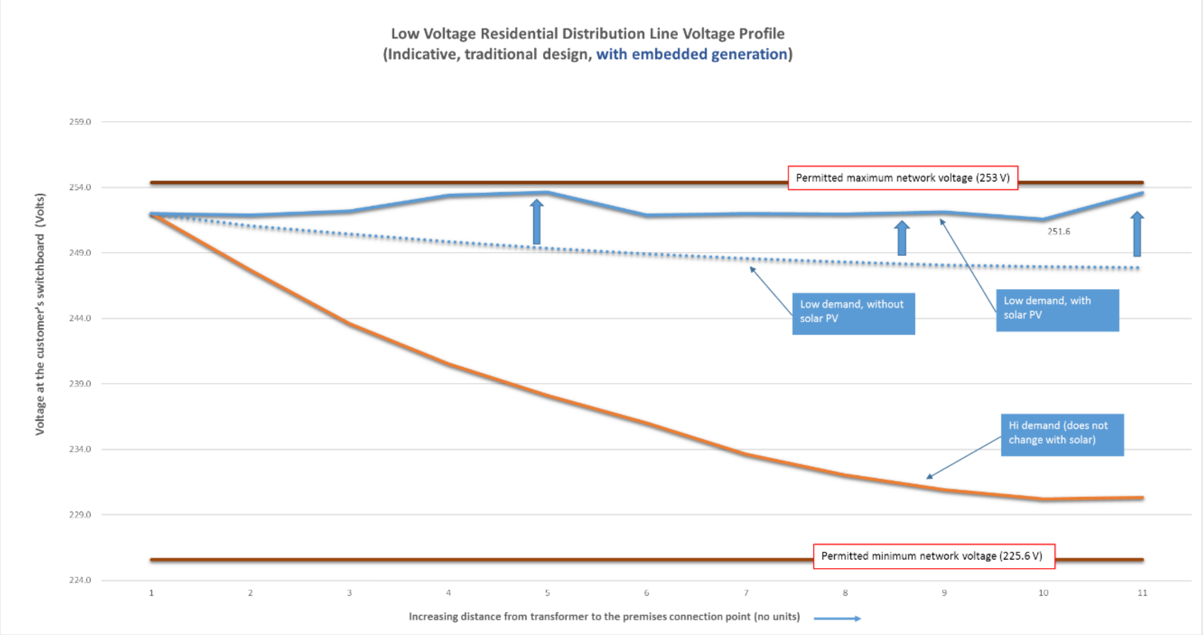
High levels of self-consumption and feed-in during daylight hours results in reverse power flow. This change in power flow is driving network voltages up in a matter not foreseen when they were designed (Figure 7).

Figure 7 – Voltage rise along a distribution power line with high embedded generation – noting the horizontal axis denotes the radial distance from the zone sub-station (Source: Ausnet Services smart meter data)



In comparison with Figure 3 (no embedded generation), Figure 8 shows the fall in voltage along the line in peak demand conditions remains unchanged, unaffected by the existence of solar PV (brown line). In low load conditions such as a sunny mild weekday however, the impact of embedded generation 'pushes' the voltage up towards the maximum allowable limit (blue lines).

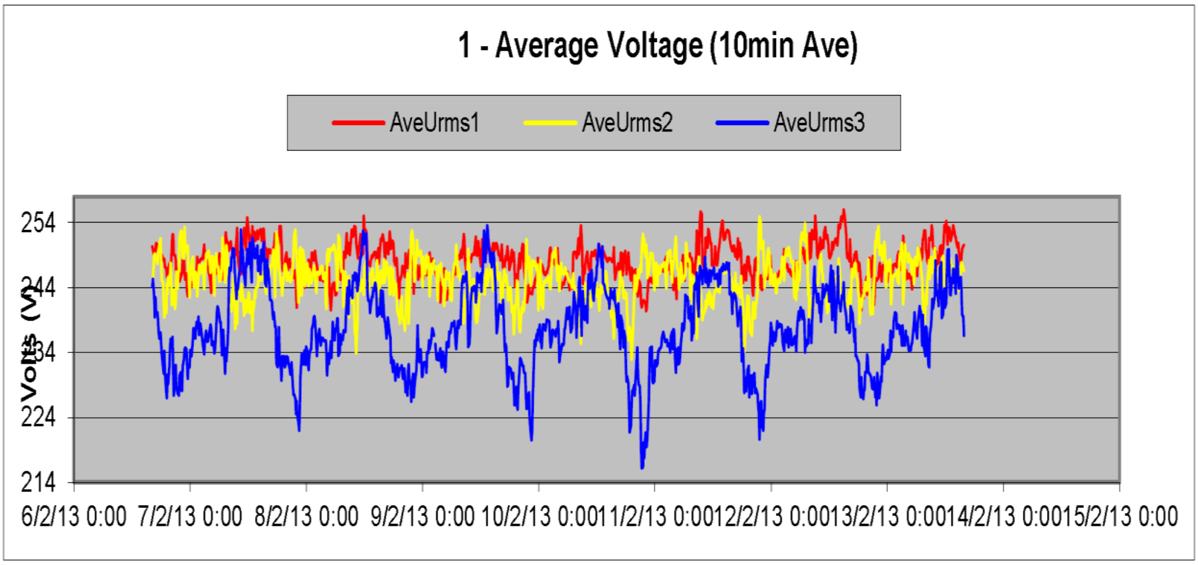
Figure 8 - Voltage Profile on a Local Low Voltage Line, with Embedded Generation. Note: the higher voltages at the connection points along the low voltage line at times of low load and energy feed-in (solid blue line) (Source: TCA)



In extreme cases of high saturation of rooftop solar PV, the blue line can cross and exceed the maximum limit. In this case, inverters can trip off, or electronics in the customer's premise can fail or suffer damage, leading to quality-of-supply complaints from customers and reduced performance of the PV system. In 2016, Energex and Ergon Energy reported around 1000 customer complaints related to solar PV and high network voltage.

Figure 9 shows voltage measurements at the end of a low voltage line with homes with solar PV, over a 9-day period in February 2013. The effect of solar feed-in during the middle of some days lifts the voltage at some premises to a level above 254 volts (the allowable maximum), yet it also falls to 215 volts (minimum permitted is 225 volts) in the evening at nearby homes on the same segment of low voltage line.

Figure 9 – High level of solar PV - noting the 'AveUrms' lines represent the 3 phases of a low voltage power line (Source: Energex Voltage Complaints Process, 2015)



1.3.1 What does supply voltage mean for customers (and appliances)?

The actual voltage of the power supply is essentially ‘invisible’ in itself to all but the more sophisticated electrical consumers with a high level of monitoring, such as local water utilities or advanced manufacturers. What is noticeable in relation to supply voltage is the impact of the voltage range, where:

- A supply voltage well over the nominal operating range (e.g. +15 per cent) can result in immediate damage and failure of equipment, particularly electronics. In extreme cases, overheating and fire is possible.
- Regular exposure to a high supply voltage (e.g. +10 to +15 per cent) can cause malfunctioning of electronic equipment and the accelerated failure of appliances.
- Regular exposure to a low supply voltage (e.g. -15 per cent) can result in poor performance of appliances and equipment.
- Exposure to very low supply voltage (e.g. -20 per cent) can cause overheating of older equipment, such as motors installed pre-1980, and the accelerated failure of some motors.

Loss of life for electrical equipment is largely related to the degradation of insulation when the machine is operated at elevated temperatures, which can occur when supplied at the lower range of rated voltage. This is a slow process and very difficult to define, because actual loss of life generally occurs during a random power supply transient (blackout, lightning strike nearby, frequent switching on and off) well after the life of the equipment has been reached. With electronic equipment, small components can have a more rapid loss of life with failure that is much more sensitive to operation at high voltages rather than lower voltages[3].

1.3.2 How is network voltage adjusted?

For the vast majority of customers connected to the shared low voltage network, the voltage is set by the 'transformer tap' on the distribution transformer that supplies the segment of mains. The transformer tap essentially adjusts the output voltage of the transformer over a range, generally up to 10 per cent of rated voltage.

The tap is generally changed 'off line'; that is, power must be interrupted to the customers for up to 30 minutes whilst the change in setting is made. Under the National Electricity Rules, four days' notice is required for customers affected by a planned power interruption. Queensland distributors report a cost of between $250 and $1000 to change a transformer tap.

2. Problem identification

A characteristic of electricity distribution networks is that high levels of energy feed-in from embedded generation causes the voltage in the local electricity network to rise. In Queensland, voltage rise is becoming more prevalent because of the increasing penetration of embedded generation[4]. On sunny days, the power supply to an increasing number of homes and businesses is at risk of exceeding the 254-volt maximum permitted in regulation. This places customer appliances at risk of failure and damage, reduces their efficiency, and shortens their operating life. The performance of embedded generators is also reduced as systems automatically disconnect to protect themselves and nearby electrical equipment from damage.

This concern has become widely evident in the last five years as the amount of embedded generation in the power distribution network has significantly expanded from 350 megawatts (MW) of installed capacity at the end of 2011 to over 1600MW at the end of 2016. The resulting two-way flow of electricity in local networks means local power lines are being used in a way that was never contemplated in the design of these assets.

A key issue is that existing statutory voltage limits in Queensland place an artificial 'floor' on electricity supply voltage. This limits the ability of distributors to address the impact of voltage rise more simply and cost-effectively by reducing the average operating voltage of networks that supply electricity to end consumers. This forces distributors to make significant investment in remediating and upgrading the network or to operate sections of the network at the upper end of the power supply limit, thereby increasing the likelihood of customer high voltage issues and complaints.

Queensland's existing statutory voltage limits of 240 volts ± 6 per cent are no longer appropriate for a contemporary electricity network where two-way power flows from embedded renewable generators is increasingly common. The narrow 12 per cent operating range is inconsistent with the more

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[3] Sweeting, D, Implications of the 230V voltage profile - report to standards committee EL/42, 2011.

[4] Energex Power Quality Strategic Plan 2015-20, p11.

progressive uniform standard of 230 volts +10 per cent/-6 per cent accepted elsewhere in Australia and overseas, and it’s permitted 16 per cent range.

2.1 What if no action is taken?

Taking no action will restrict opportunities for distributors to reduce voltage as a way of managing the network impact of embedded renewable generation, with the following consequences:

Distributors will continue to rely on more expensive options to manage voltage rise, such as significant operating and capital investment in the low voltage networks.

In its final regulatory determination, the Australian Energy Regulator (AER) allocated Energex and Ergon Energy $24 million[5] and $26 million[6] respectively to manage voltage rise and maintain power quality on Queensland networks for the 2015 to 2020 regulatory period. Advice from distributors indicated that the actual cost will be in the order $109 million ($59 million for Energex and $50 million for Ergon). This includes expenditure on network augmentation, operating practice changes, addressing customer voltage complaints and installing monitoring equipment on the network to provide early warning of power quality concerns.

Distributors will field an increasing number of high voltage complaints from customers.

For customers with existing solar PV embedded generators, the occurrence of voltage rise places customer appliances at risk of failure and reduces the performance of embedded generators as they automatically disconnect to protect themselves and adjacent electrical appliances at times of high voltage. In extreme cases, appliances that run at voltage levels well above the median (e.g. +15 per cent) run the risk of overheating and causing fires.

At present, the distributors receive about 1000 high voltage complaints per year. Energex and Ergon Energy advise that it costs $2,200 on average to field and investigate each complaint at a total cost of $2.2 million per year. In addition, insurance claims for appliance damage associated with voltage rise cost distributors about $60,000 per year.

Data from Energex indicates an increasing trend in the number of customer complaints from high connection voltage since 2010-11 (Figure 10).

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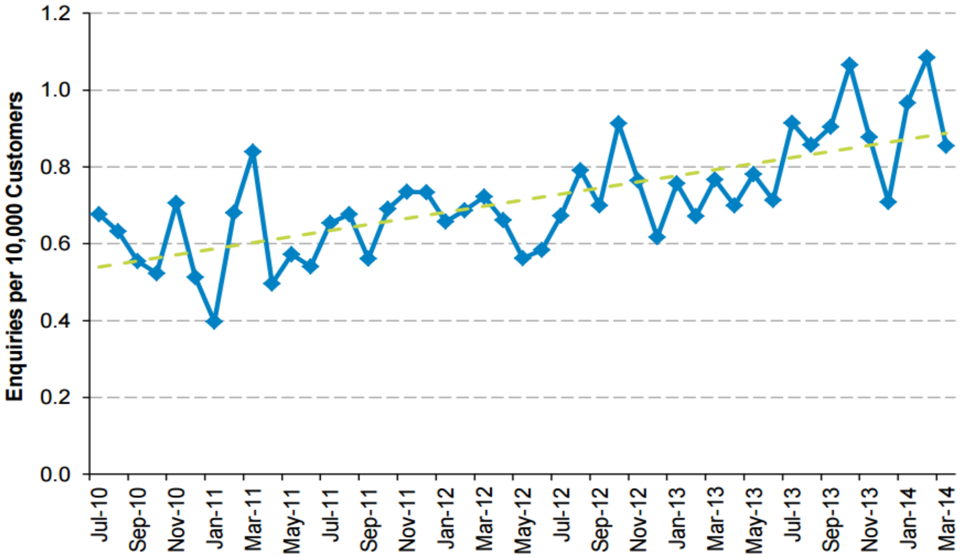
[5] Australian Energy Regulator, Final Decision Energex Attachment 6 – capital expenditure, p6-36.

[6] Australian Energy Regulator, Final Decision Ergon Energy Attachment 6 – capital expenditure, p6-46.

Figure 10 – Energex high voltage complaints



Under the current regulatory arrangements, customer high voltage complaints may continue trending in this direction, causing significant additional cost for distributors to investigate and address them. These additional costs are ultimately passed through to electricity customers.

Distributors will restrict the connection of embedded generation to the network, limiting the use of the network to export or trade distributed energy as network hosting capacity is reached.

Distributors' connection guidelines place limitations on the network connection of embedded generation to manage high voltage. This means many solar connection applications go through the technical assessment process with the effect of adding time (and in some cases cost) to the process of installing a solar PV system.

Technical assessments may require customers to modify the size (or export capacity) of their chosen system, restrict the system's ability to export excess solar generation to the grid or, for larger systems, pay a capital contribution (of between $10,000 and $60,000) toward the cost of a network upgrade before the system is installed. This can impact the attractiveness and financial viability of installing solar PV for some customers, and the renewable energy industry's ability to grow.

Energex recently identified that almost 1-in-10 distribution transformers were likely to record voltages greater than that permitted under current regulation, with 11.5 per cent of customers likely to experience voltage at or above the 99th percentile of permitted voltage[7]. On this basis, it is considered likely that 10 per cent of new applications for new rooftop generation (around 200 per month) will require modification or be refused.

Feedback from industry is that current solar connection processes are challenging the growth of Queensland's renewable energy industry. Furthermore, it is expected that as solar PV penetration increases in Queensland, a point may be reached in the future where customers are locked out of installing rooftop solar altogether because some sections of the network have limited capacity to

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[7] Energex Power Quality Strategic Plan 2015-20, p10.

safely host embedded generation. This may result in further restrictions on the grid connection of exporting solar PV systems in the future, leading to poor outcomes for customers and a potentially detrimental effect on the Queensland's renewable energy industry.

Queensland voltage standards are inconsistent with other Australian states and do not reflect international best practice.

As early as 2004, the Council of Australian Governments (COAG) released Principles and Guidelines for National Standard Setting by Ministerial Councils. A goal of the guide is to adopt regulatory measures or standards that are compatible with relevant international or internationally accepted standards or practices in order to minimise any impediments to trade. Failing to adopt a uniform standard nationally for voltage is inconsistent with the COAG Energy Council objective to ensure efficient investment and operation of electricity infrastructure[8].

Queensland Government initiatives for further development of renewable generation and supporting new market frameworks (such as peer-to-peer energy trading) will proceed at a higher cost to energy consumers.

The Queensland Government is committed to delivering its Solar Future policy. Included in the initiative is a target for one million solar rooftops or 3000 megawatts of installed solar capacity in Queensland by 2020. The aim of this policy target is to help grow the renewable energy industry, lower electricity costs for families and businesses, create jobs and protect the environment by reducing greenhouse gas emissions.

A key aim of the government policy is that the development of solar PV does not add to unreasonable costs for Queenslanders. Should the statutory voltage limits fail to reflect the current trends and demands of changing customer energy use, distributors will be forced to take a less efficient approach to managing voltage rise in the future and government's cost objectives are less likely to be met.

Modern electrical equipment will continue to be operated at the upper end of its operating voltage parameters, increasing the risk of appliance damage, poor performance and reduced product life.

With consumer electrical appliances and equipment being manufactured for global markets, maintaining the current voltage standard means that modern electrical equipment used by households and small businesses will operate at the higher end of its operating range.

The majority of appliances purchased for consumer use in Queensland since the late 1980s have been constructed to the international standard of 220 – 240 volts. In areas of high solar PV penetration, power supply voltages of above 250V are common. International studies have shown that average energy consumption by common appliances can increase by approximately 0.65 per cent for every volt above nominal efficient rating. Appliance effective service life before failure is reduced when operated over nominal voltage[9].

With an estimated $4 billion worth of household appliances in Queensland homes, a conservative estimate of 0.1 per cent would result in reduced appliance life/appliance failure of approximately $4 million per year.

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[8] COAG Energy Council, Energy Market Transformation, December 2015

[9] Linden, K and Segerqvist, I, Modelling of Load Devices (appliances), Chalmers University of Technology, 1992

3. Objectives of Queensland Government action

The objective of this work is to consider if aligning Queensland's statutory voltage limits with Australian and international standards will allow more efficient management of voltage issues caused by the high penetration of solar PV in Queensland and support greater levels of renewable generation in line with the Queensland Government's overarching energy policy objectives of:

- delivering stable energy prices
- ensuring long-term security of electricity supply
- transitioning to a cleaner energy sector
- creating new investment and jobs.

4. Consideration of options and impact analysis

Based on the recent assessment of Queensland's solar PV connections framework and additional research, analysis and targeted stakeholder consultation, this RIS identifies five possible approaches to achieving the stated policy objectives (Table 3).

Table 3 – Options in respect of the regulation of Queensland's statutory voltage limits

Option	*Description/Operation*
Option 1: Business as usual – No regulatory change	*Description* - Maintain existing requirements prescribing network voltage as 240 volts of +6/-6 per cent. *Operation* - Distributors will act to correct distribution voltages and upgrade the network to ensure the electricity supply is within statutory limits as part of regular operating augmentation schedules over the next two regulatory periods (7 years).
Option 2: Regulatory change – Adopt the national standards for voltage and power quality with a 6 to 8-year transition to full compliance with the power quality requirements.	*Description* - Adopt the national standard for power supply voltage of 230 volts +10/-6% (AS60038:2012) and the standard for Limits of Steady-State Voltage in Public Electricity Systems (AS61000.3.100:2011). *Operation* - Distributors will act to correct distribution voltages that exceed (the new) regulated limits as part of regular operations over the next two regulatory periods (7 years).

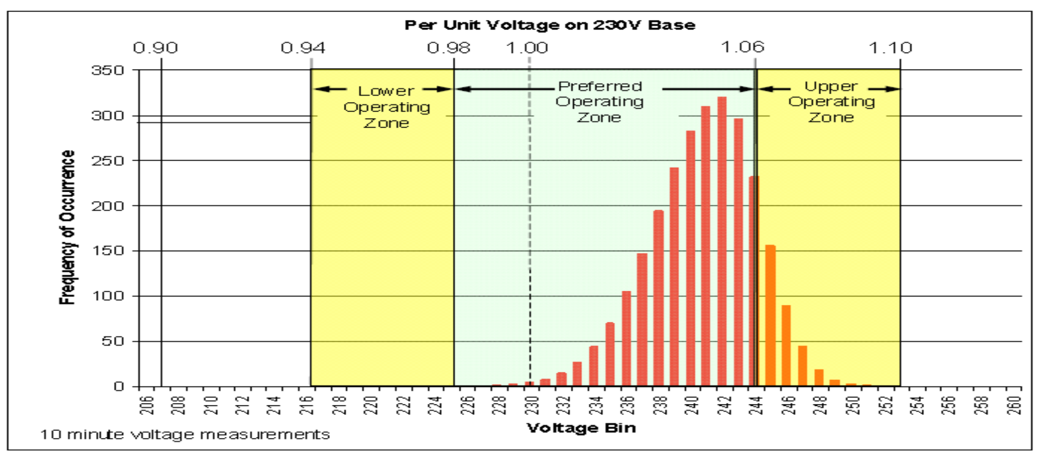
Option 3: Regulatory change – Adopt the national standards for voltage and power quality with a 3 year transition to full compliance with the power quality requirements.	*Description* - Adopt the national standard for power supply voltage of 230 volts +10/-6% (AS60038:2012) and the standard for Limits of Steady-State Voltage in Public Electricity Systems (AS61000.3.100:2011) *Operation* - Distributors will specifically allocate resources to correct distribution voltages that exceed (the new) regulated limits as part of a planned work program over the next 3 years.
Option 4: Regulatory change – Develop and adopt an innovative voltage and power quality standard.	*Description* – Consider the application of a wider range of voltage (e.g. 230 V ± 10 per cent) than that specified in the national standard, with the possible benefit of further reductions in expenditure by distributors. *Assessment* –Research conducted in the United Kingdom and Europe found that this approach risks failure to legacy appliances and equipment, such as small irrigation pumps manufactured prior to 1990 but it may be viable in the future (Eurelectric - EU Electricity Industry, November 2003). The approach is therefore discounted as it is inconsistent with other National Energy Market jurisdictions and does not reflect current international best practice. For these reasons, no further consideration of this option is made in the RIS.
Option 5: Adopt a self-regulation regime	*Description* – Consider the removal of Queensland power supply voltage requirements and use market forces or other legislation to deliver safe and effective outcomes. *Assessment* – Given that distribution networks are regulated monopolies, there is insufficient empowerment of customers and market competitive forces to ensure standards are maintained and therefore a non-regulatory option is not considered further in this RIS.

4.1 Benefits of ‘voltage optimisation’

A word about AS61000.3.100

This standard introduces statistical measurement and definition of electricity supply voltage levels and the concept of a ‘preferred operating zone’ for the voltage of power supply. Features of the standard include a preferred median voltage range that is designed to provide for greater customer equipment end use efficiency, increased equipment life and the continuing installation of embedded generation. Figure 11 illustrates the concept of operating zones for voltage under the standard, where a number of measurements are made over a set period, and the frequency of occurrence of each voltage is plotted.

Figure 11 – Voltage distribution as per AS61000.3.100 (Source: Standards Australia)



A number of studies from the UK and Europe, in conjunction with recent work by Energex and Ergon Energy have identified a positive relationship between generally lower network voltages resulting from a ‘preferred operation zone’ and energy efficiency and demand reduction[10].

Known as ‘voltage optimisation’, a number of factors relating to the efficient operation of electrical equipment have been identified. In 2015 at the 23rd International Conference on Electricity Distribution, it was concluded that the performance of appliances is most efficient when operated at the midpoint of its voltage rating[11]. Power supply voltage that is optimised to match appliance design is noted to offer two forms of energy reduction:

- load reduction for devices that are constant impedance or constant current, such as incandescent lighting and heating
- efficiency gains for devices that run more efficiently at a lower voltage because of a reduction in losses and lower operating temperatures (modern electronics, some motors and white goods).

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[10] Descheemaeker, J, Van Lumig, M, Influence of supply voltage on the performance of household appliances, CIRED, 2015.
[11] Ibid.

In practice, reduction in demand does not translate linearly to reduced energy consumption (kilowatt-hours). Lower power in appliances that require a fixed amount of energy to carry out their task, such as water heating or cooking, will take slightly longer to complete the required task. However, a number of distributors in Australia have reported reduced energy consumption in typical residential and commercial situations[12].

4.2 Cost benefit analysis approach

A comprehensive cost benefit analysis (CBA) has been undertaken to ascertain the impacts of each proposed option on the community, industry and government. The costs and benefits have been calculated over a period of 10 years (2017 – 2027) to align as far as possible with regulatory determination periods. Analysis over 20 years was considered to be less meaningful given the likely changes to technology and the industry over this period.

The CBA is informed largely by data gathered as part of an Ergon Energy desktop study on the impacts of adopting the Australian voltage standard on sections of its network and data provided by Energex. The Ergon study assessed the impacts of moving to the national standard on three urban and three rural feeders. This data has been extrapolated to Ergon's network of 452 feeders for the purpose of the CBA. For Energex, best estimates of savings on expected ‘business as usual’ costs have been estimated by the distributor in the absence of specific trial data, noting that augmentation savings would likely be similar per feeder to those of urban feeders in the Ergon Energy trial.

The CBA base case considers the estimated *actual* voltage costs that the distributors expect to incur if the voltage standard is not changed, as opposed to the costs approved by the AER. The CBA also uses the following discount rates for different customer groups in its analysis of impacts related to a move to the 230-volt standard:

- 4.87 per cent - general discount rate for residential customer groups (assumed long-term variable housing rate analysis)
- 5.70 per cent - Ergon Energy retail discount rate (regulated margin, Queensland Competition Authority (QCA) 2016-17 regional price determination)
- 6.01 per cent - Ergon Energy and Energex distribution networks discount rate (AER 2015-2020 regulated revenue determinations)
- 8.00 per cent - general business discount rate for business customers, solar installers, SEQ retailers, and generators (assumed commercial weighted average cost of capital (WACC) value for analysis).

In its submission to the Consultation RIS, Origin Energy commented that the CBA did not appear to account for an increase in network losses as a result of a reduction in voltage. It is acknowledged that the proposed decrease in average network voltage will result in a minor increase in network losses for constant power loads. However, the expected reduction in demand for electricity and additional uptake of distributed generation as a result of this proposal (modelled at 40MW by 2020) is expected to reduce overall network losses and enhance network efficiency. DEWS considers the overall impact

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[12] Energex Limited, Transition to the 230V standard – Impacts to Customers and the Network, October 2015, p7.

of network losses on the CBA is small to negligible and therefore, they are not factored into the analysis.

4.3 Option 1 – Base case

Option 1 would see no changes to Queensland's existing statutory voltage limits, meaning that Energex and Ergon Energy will take a business as usual (BAU) approach to maintaining network supply voltage within the limits set out in the *Electricity Regulation 2006*. Table 4 provides a summary of the qualitative and quantitative impacts of taking no action as described in detail in Section 2.

Table 4 – Summary of stakeholder impacts under the base case

Summary of Stakeholder impacts (Option 1 base case)	
Impact	**Stakeholder affected**
$109 million ($59 million for Energex and $50 million for Ergon Energy) in operating costs to address voltage rise in the next regulatory period.	Distributors
$2.2 million per year to address customer high voltage complaints.	Distributors
$60,000 per year in insurance claims for appliance damage associated with voltage rise.	Distributors
Increased risk of voltage rise causing appliance failure/damage at **10 per cent** of all premises.	Customers
Reduced appliance life of approximately **$400,000** per year.	Customers
An upward trend in customer complaints or poor inverter performance over the current regulatory period (based on current forecasts).	Customers / Distributors
Solar PV systems with an export capacity over 3.5KW in regional Queensland will continue to undergo technical assessment and possible energy export restriction.	Customers / Solar industry
A continued process of restricting energy feed-in for many embedded generators, thereby restricting the application of new energy markets and the uptake of new technology, and reducing the attractiveness of investment in new technology for customers.	Customers / Solar industry

A slow-down in the uptake of rooftop solar as network capability to absorb energy feed-in within regulated limits saturates, and the current network capacity threshold of 30 per cent of customer energy demand is reached in more locations.	Solar industry / government
The ongoing inability of distributors to address voltage rise by lowering the network supply voltage to a level that provides a more efficient operation of modern electrical appliances.	Distributors

4.4 Option 2 – adopt the national standards for voltage and power quality, with a seven-year transition to full compliance with power quality requirements

Under Option 2, Queensland would amend the *Electricity Regulation 2006* to adopt the voltage and power quality measures set out in Australian Standards AS60038 and AS61000.3.100 over one year and seven years respectively.

This means distributors would be given a one-year transitional period to comply with AS60038 (i.e. operate the network within a range of 216 to 253 volts). Given current voltage limits lie largely within this range (with the exception of 1.4 volts at the top of the range), one year is considered a sufficient timeframe for distributors to:

- lower supply voltage levels on sections of the network identified as being at greater risk of operating outside the new permitted operating range (likely above the permitted maximum)
- identify and address any contractual issues linked to the current voltage requirements.

The modelling then assumes the distributors will comply with AS61000.3.100 over a period of seven years. This means Energex and Ergon Energy will have seven years to adjust supply voltage to ensure the network operates within a range of approximately 225 to 244 volts (the preferred operation zone) inherent in this standard.

4.4.1 Option 2 – qualitative impacts

Qualitative impacts

Distributors advise that adopting the national standards for voltage and power quality in Queensland will enable solar PV hosting capacity to increase from 30 per cent to 45 per cent in some sections of the network. In addition, Ergon Energy has advised that the new requirements will enable:

- an increase in the technical assessment threshold for embedded generator connection applications from 3.5kVA export capacity to 5kVA
- auto-approval of connection applications for 10kVA systems with a 5kVA export capacity (on a single phase) without the need for a technical assessment.

This is expected to allow more embedded generation to be integrated into the network and improve the customer connection experience by:

- increasing the number of auto-approved connection applications (i.e. immediate approval of connection applications)
- speeding up the connection process for many customers and in some cases, reducing the cost of connection (under the National Electricity Rules, distributors can take up to 65 business days to connect an embedded generator to the grid)
- reducing the need for distributors to modify connection applications
- increasing the number of connection applications that progress to installation.

An environment where it is easier (and potentially, cheaper) for customers to connect solar PV to the grid is expected to increase the attractiveness of solar for customers, support ongoing growth in the solar PV industry, contribute to the Queensland Government’s solar targets and support its broader renewable energy policy objectives.

In addition, the risk to customers associated with appliance failure/damage as a result of operating at very high voltages will diminish under this approach.

Conversely, there is a small level of concern that some electrical equipment such as appliances and motors pre-dating the 1980s may not operate to the same level of performance at a lower voltage. Consultation indicated that the number of these appliances in use in Queensland is minimal. Investigation also found that it would be difficult to establish the extent to which the failure of older appliances could be attributed to operation at lower voltage as opposed to the appliance simply reaching the end of its operating life. As such, the impacts of this risk are not considered further in this RIS.

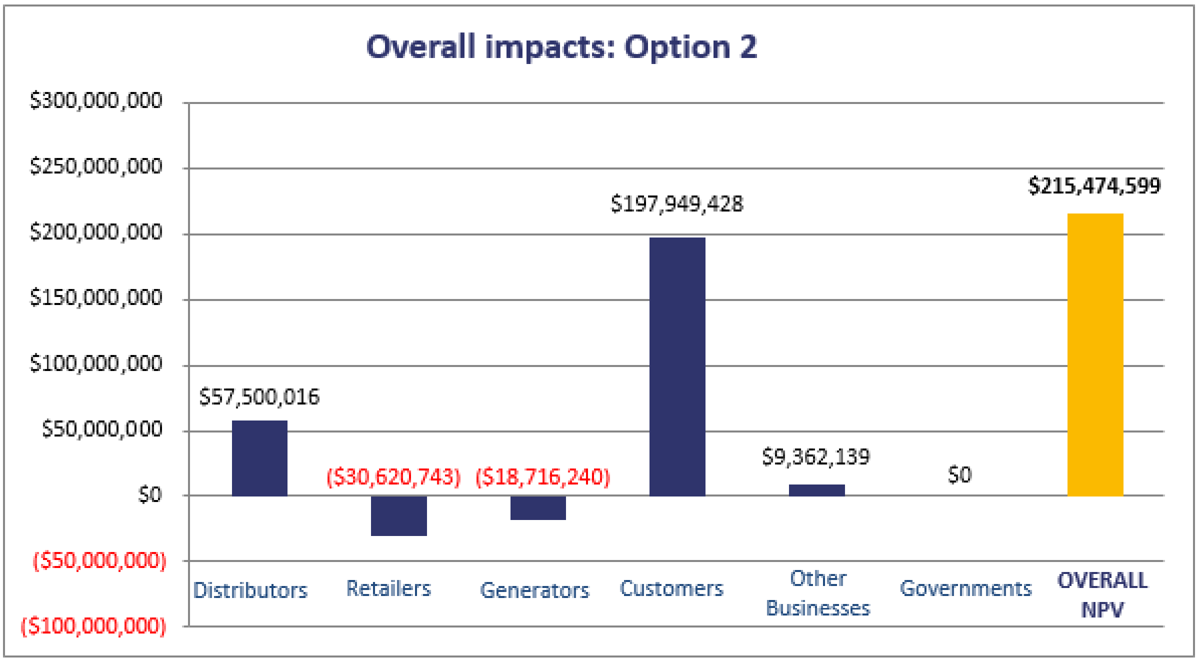
Another risk identified during the scoping of this RIS was that street lighting manufactured before 2000 may experience a reduction in luminance if network voltage limits are reduced. However, consultation with distributors in Queensland and other jurisdictions has indicated that this will have a negligible impact as street lighting design has assumed the uniform standard for voltage since 2004.

Environmental emissions reductions have been calculated for the RIS, but no additional economic value has been attributed to these reductions.

4.4.2 Option 2 – Net present value

The total NPV benefit of Option 2 (measured against the base case) is approximately $215 million. Figure 12 summarises the costs and benefit across affected stakeholder groups.

Figure 12 – Option 2 overall impacts



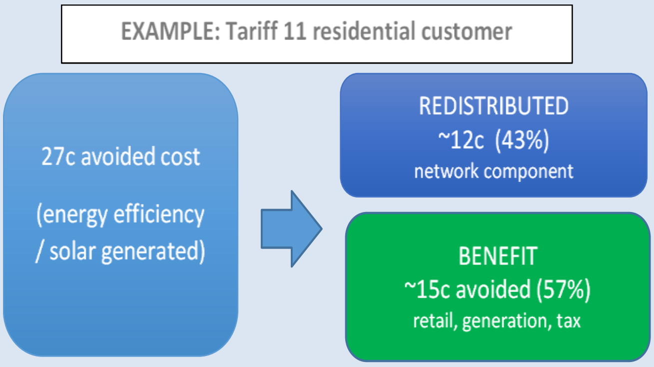
The impacts of reduced energy use

Different customers are charged different prices for their energy usage. For the purposes of this analysis, it is assumed that all residential energy is purchased at 27.070c/kWh (Ergon Energy tariff 11) and all businesses buy electricity at 28.564 c/kWh (Ergon Energy tariff 20). Due to the inherent difficulties in calculating associated energy efficiency benefits for large customers on demand tariffs, a lack of data for this customer group, and given many large customers are connected to the transmission network (rather than the distribution network), we do not include this customer group in the analysis.

Modelling estimates that around 2400 gigawatt hours (GWh) (Option 2) of grid electricity consumption will be avoided over 10 years relative to the base case. This is due to increased rooftop solar PV and the more efficient operation of electrical appliances and equipment at lower network supply voltages.

The economic impacts of reduced energy use

The use of less grid power has both costs and benefits for customers. Customers' electricity costs reduce as they avoid some retail, generation, and GST cost components of their own variable electricity charges.



Based on QCA-regulated regional tariff structures for residential and business customers the saving is around 57 per cent of the total cost they pay for of each kWh of energy. The other 43 per cent is distribution use of service (DUOS) charges (i.e. the network component of electricity tariffs), which are redistributed to other customers via an increase in the DUOS cost per kWh (as the total cost of the network is recovered over fewer total kWhs of energy).

Lower energy use means lower costs but also lower profit for generators and retailers. Using the 2016-17 QCA price determination, Table 5 estimates the impacts per kWh across all Queensland residential and business customers in year 1 (modelling assumes tariffs escalate by 2 per cent CPI per annum). As the generator mix of cost and margin* is not available in the determination, the modelling assumes 12 per cent of the generator component is profit margin (see section 4.4.3).

Table 5. Allocation of avoided consumption per kWh

Variable Charge Component	Residential Tariff (T11)		Business Tariff (T20)	
	c/kWh	% of total	c/kWh	% of total
Network	11.624	42.9%	12.486	43.7%
Generator margin*	1.133	4.2%	1.133	4.0%
Generator costs*	8.312	30.7%	8.312	29.1%
Retailer margin	1.540	5.7%	1.625	5.7%
Retailer costs	2.001	7.4%	2.411	8.5%
GST	2.461	9.1%	2.597	9.1%
TOTAL	**27.070**	**100%**	**28.564**	**100%**
Total redistributed costs	11.624	42.9%	12.486	43.7%
Total avoided margins	4.756	17.6%	4.977	17.4%
Total avoided costs	10.690	39.5%	11.101	38.9%

In effect, for each kWh avoided, customers benefit (by 15 cents accounting for the pass through of avoided network charges, and retailers and generators are negatively impacted. While retailers and generators forego margin they also avoid costs , therefore overall benefit saved by customers is greater than the loss to generators and retailers.

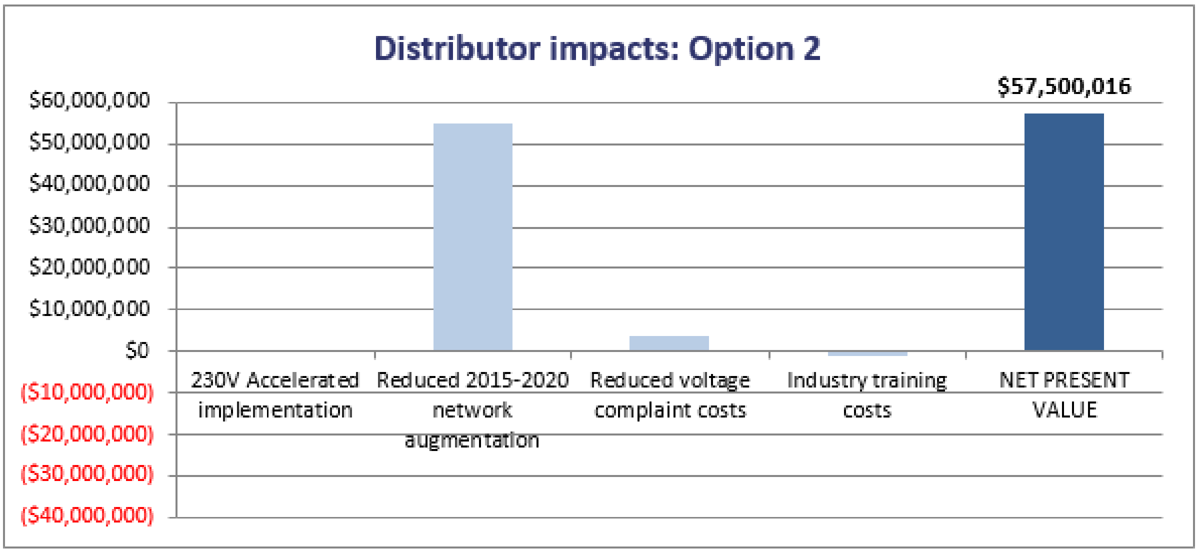
Impacts:

~15c costs avoided by customers
~12c costs redistributed to distributors
~8c costs and ~1c revenue avoided by generators
~2c costs and ~2c revenue avoided by retailers
~2c GST revenue avoided (assumed to be replaced elsewhere in the economy – see section 4.4.7).

4.4.3 Option 2 impacts – distributors

The NPV benefit for distributors is approximately $58 million with benefits accruing as a result of reduced network augmentation expenditure and reduced expenditure in dealing with customer voltage complaints (Figure 13).

Figure 13 – Option 2 distributor impacts



4.4.3.1 Benefits – distributors

Base case network augmentation and related operating costs to address voltage rise are estimated to be $109 million for the current regulatory period ($59 million for Energex and $50 million for Ergon Energy). Under Option 2, these costs reduce to $39.2 million for Energex and $14.7 million for Ergon Energy because the distributors would be able manage voltage rise at lower cost by lowering network supply voltage rather than by upgrading the network. This results in savings of $20 million and $35 million respectively, or a total reduction of approximately $55 million.

The analysis assumes there is no impact from network augmentation expenditure beyond the 2020 to 2025 regulatory determination period.

Augmentation expenditure savings

Queensland's government-owned energy distributors Energex and Ergon Energy are independently regulated by the AER because energy distribution is considered a 'natural monopoly' in Queensland. Allowable revenue is determined in five-year periods using a regulated 'building block' model. Capital expenditure, operating expenditure, tax, depreciation and a margin for return on assets are assessed by the AER and used to determine the maximum allowable revenue over the five-year period.

Although the AER allocates money to the distributors to spend on specific activities such as network augmentation to address voltage and power quality requirements (as a proportion of their total revenue determination), the final determination is essentially a single pool of funds the distributors can draw on as they see fit to operate the network efficiently. For example, the AER has allocated approximately $52 million to address voltage rise and power quality issues in the current regulatory period but distributors estimate this cost at $109 million. This means that distributors will need to draw on funding allocated to another area of their business or overspend their budget to comply with current voltage arrangements.

The network augmentation savings resulting from this proposal (approximately $55 million) are not expected to impact the overall revenue distributors earn in the current regulatory period. However, these savings will likely be used to fund projects/programs aimed at improving network efficiency or otherwise benefiting customers. In the event that network augmentation savings are not spent elsewhere by the distributors, they will be carried over to the next regulatory period. For these reasons, network augmentation savings resulting from this proposal are treated as a net benefit to distributors in the CBA.

The modelling further assumes that any savings in network expenditure post-2020 that are associated with a change in voltage requirements would result in a lower approved augmentation expenditure allowance by the AER in that regulatory period than would have occurred under the 240V case. This means that customers would be the beneficiaries of any post-2020 network savings.

The majority of benefits to augmentation expenditure relate to avoiding current planned works and are therefore expected to occur in the distributors' current regulatory period. Post-2020 benefits are estimated based on *future solar PV uptake costs* identified in a 2016 Ergon Energy 230V trial[16]. The trial found that larger future solar PV benefits are achieved in urban regions than in rural regions (noting data limitations exist due to the small sample size used in the trial). For the Energex network area, post-2020 savings are estimated by extrapolating the urban component of the Ergon Energy trial to the size of Energex's network.

On this basis, 2020-2025 augmentation savings are estimated to be $2 million for Ergon Energy and $14 million for Energex, reducing the augmentation expenditure allowances in that period (on what would otherwise have occurred) and flowing through as a benefit for customers. Benefits beyond 2025 are assumed to be nil.

In addition, distributors will also see a reduction in expenditure of approximately $5 million ($2.5 million each) as a result of an assumed 40 per cent reduction in customer high voltage complaints. This is based on advice from Energex and Ergon Energy that voltage complaints are expected to decrease as work is carried out (as part of their standard operation and maintenance schedules) to meet the new voltage and power quality requirements.[13][14]

The distributors have highlighted a potential risk of increased low voltage complaints as network voltage supply is lowered under Option 2. However, consultation with distributors in South Australia and New South Wales did not identify any significant increase in low voltage complaints after the relevant Australian Standards were adopted in those jurisdictions. On this basis, this is considered a minimal risk and is not further factored it into the analysis.

4.4.3.2 Costs - distributors

Advice from the electrical contracting industry is that under Option 2, some costs will be incurred to notify electricians and designers working in the electrical industry of the adoption of the new voltage and power quality standards and to integrate these standards into their work. Communications and training will be initiated by distributors through normal channels and published local rules and guidelines will need to be amended to reflect the new regulations at an estimated cost of $1 million. As the 230-volt standard is implemented as part of BAU maintenance for the distributors under Option 2, no accelerated implementation costs are incurred.

4.4.4 Option 2 impacts – retailers and generators

Electricity retailers are expected to incur an NPV cost of approximately $31 million under Option 2 (Figure 14). This impact is divided between Ergon Energy Retail ($14 million) and other retailers trading largely in South East Queensland ($16 million). This net loss is the result of avoided consumption due to better appliance operating efficiency and increased uptake of solar PV by residential and business customers (see ‘The impacts of reduced energy use’, page 20).

Generators are expected to incur a NPV loss of approximately $19 million under Option 2, for the same reasons.

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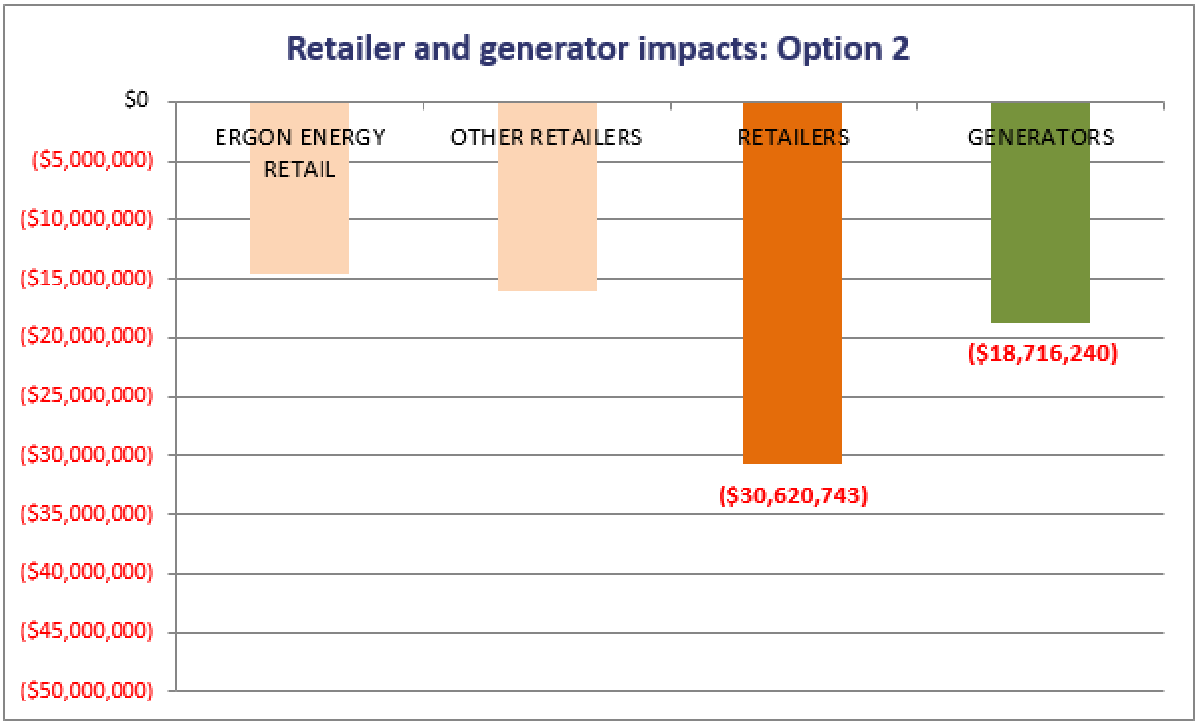
[13] Ergon Energy and Energex, Queensland Government 230V cost-benefit analysis: draft options and assumptions – Ergon and Energex comments, December 2016, p2.

[14] Ergon Energy, Progress report on findings to date in a trial to transition to a 230 Volt Standard, July 2016, p2.

Figure 14 – Option 2 – Retailer and generator impacts



Retailer margin for Ergon Energy is set by the QCA at 5.7 per cent of the total retail electricity price, and for the purposes of this RIS, retailers in SEQ are assumed to accrue the same margin.

Margin on energy consumption for generators differs greatly between businesses and is not observable. For a generator to remain profitable, energy sales must recover fixed costs, variable costs, debt costs, and equity costs. Based on a cost of equity of 12 per cent[15] and a cost of debt of 5 per cent, a weighted average cost of capital (WACC) of 9 per cent is estimated. The analysis assumes a further 3 per cent is required for fixed cost recovery bringing the generator margin on each kWh to 12 per cent of the total generation component of electricity costs to customers.

4.4.5 Option 2 impacts – electricity customers

The total NPV benefit for electricity customers is expected to be approximately $198 million (Figure 15). This benefit accrues to residential and business customers largely through avoided electricity consumption and the installation of more solar PV. Figure 15 shows the distribution of costs and benefits for:

- new residential solar customers
- new business solar customers
- residential electricity customers (including existing solar customers)
- business electricity customers (including existing solar customers).

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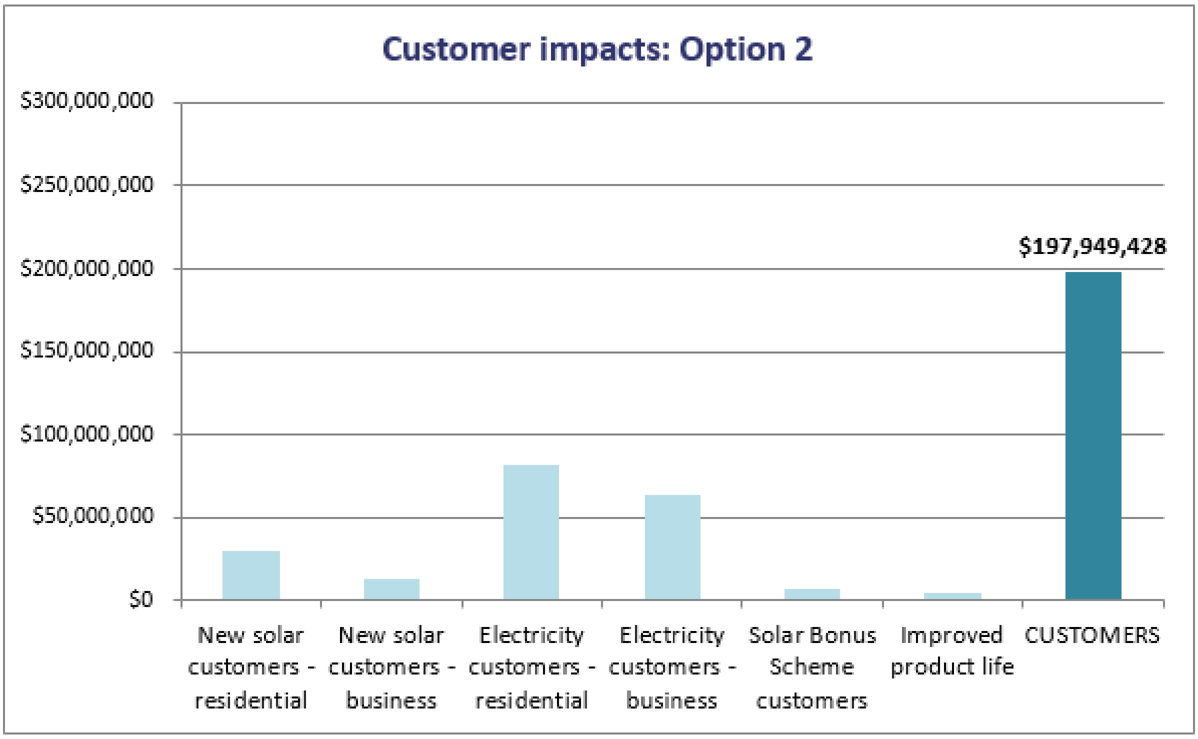
[15] Simshauser, P. & Ariyaratnam, J, What is Normal Profit for power generation?, AGL Journal of Applied Economic and Policy Research, Working Paper 38, 2013.

One of the limitations of the analysis is that it assumes the continuation of the current flat residential tariff structure. Any large scale movement of residential and business customers to alternative tariff structures (such as demand charging) could alter the outcome of this analysis.

Figure 15 – Option 2 customer impacts



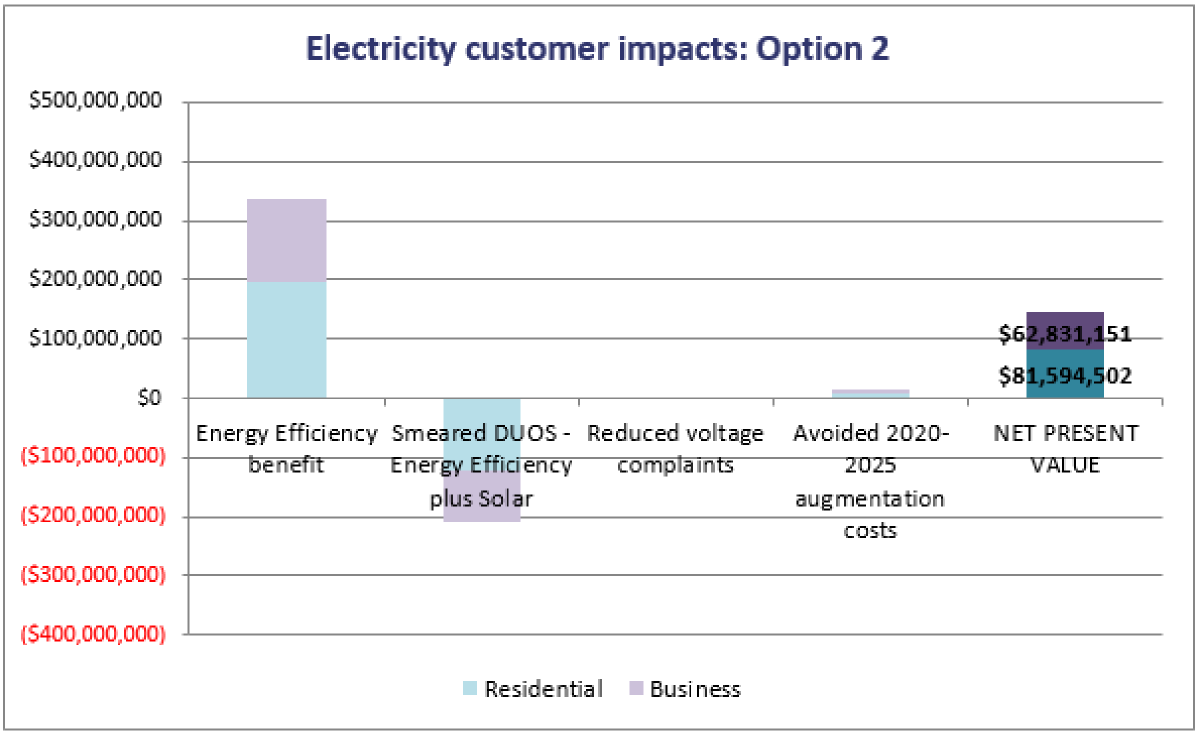
The distribution of customer benefits is discussed further below.

4.4.5.1 Benefits – residential and business customers

Under Option 2, the total NPV benefit for residential and business customers is approximately $144 million ($82 million for residential customers and $63 million for business customers). This equates to an average saving of approximately $40 per household over 10 years and $300 for businesses noting that there is a large variation in benefits between different sized business customers.

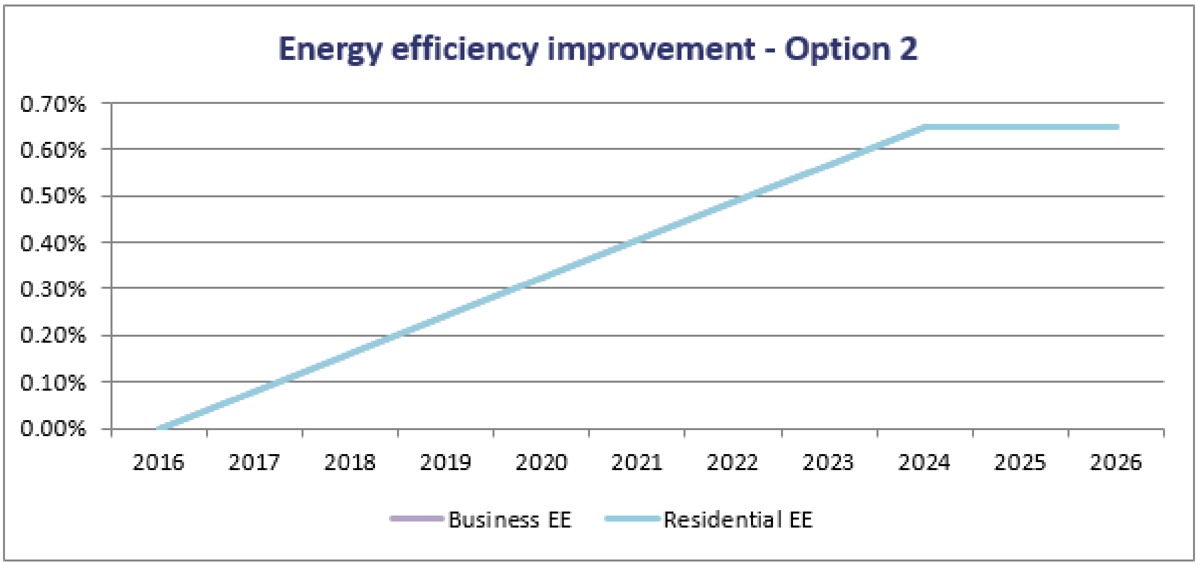
Figure 16 shows a breakdown of the economic impacts on residential and business customers. The breakdown includes total energy efficiency benefits (before consideration of redistributed distribution use of system (DUOS) effects) of $196 million to residential customers and $141 million for business customers, and includes approximately $16 million ($10 million for residential customers and $6 million for business customers) in avoided network augment costs during the 2020 to 2025 regulatory period.

Figure 16 – Option 2 electricity customer impacts



Customer energy efficiency benefits assume a 0.65 per cent efficiency improvement in the running of appliances, ‘ramping up’ over seven years (Figure 17). This is based on Ergon Energy trial data and a Conservation Voltage Reduction trial report prepared by Ausgrid and the Federal Department of Industry, Innovation and Science[16] and is expected to lead to an estimated 1530GWh in avoided consumption across these customers.

Figure 17 – Option 2 energy efficiency improvement



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[16] Dalitz, C, Discussion Paper Conservation Voltage Reduction, 2016.

Residential and business customers are also expected to benefit in terms of time, cost and inconvenience, through an assumed 40 per cent reduction in voltage complaints. However, in the absence of data to inform an estimate of the economic cost to the customer per complaint, this impact has been omitted from the analysis.

Another benefit accruing to these customers under Option 2 is an estimated $4 million in extended product life due to appliances and equipment operating closer to the mid-range of their operating parameters. This is based on international studies which indicate a premature failure rate in appliances of 0.1 per cent when operated at the upper end of the rated supply voltage range[17], and based on an estimated $4 billion in value of household appliances in Queensland.

4.4.5.2 Costs – residential and business customers

Figure 16 shows that customer benefits are offset to some extent by approximately $222 million in additional DUOS charges passed through via network charges as a result of lower grid power usage ($124 million for residential customers and $84 million for business customers).

In its submission to the Consultation RIS, Origin Energy raised concern that the differences in the upper and lower limits under the two voltage standards (240 volts vs 230 volts) will mean a number of solar inverters currently installed in Queensland become ‘non-compliant’ with the proposed 230 volt standard. Furthermore, Origin suggested that this may lead to system errors where grid voltage is outside (lower than) an inverter’s set operating voltage range and create additional costs for customers to rectify.

It is important to note that the compliance of grid connected inverter energy systems is determined by the technical connection standards published by Energex and Ergon Energy. These specifications have evolved in the last number of years, including major revisions to better match AS4777.2:2015. In all cases, the current protection setting requirements in the connection standards are outside the distributors’ permitted voltage range.

Discussions have been held with distributors, solar PV installers, industry peak bodies and inverter manufacturers to better understand the risk of nuisance tripping of inverters due to low network voltage.

Advice from manufacturers is that inverters are rated for operation between 180 volts and 270 volts (noting that this range may differ between products) and as such all inverters can operate safely within both the current and proposed voltage ranges.

Distributors advise that connection requirements published prior to 2015 were silent on the matter of low-voltage trip setting, and the applicable Australian Standards AS4777 did not provide guidance on the matter at that time. However, since 2015, standards and connection requirements have nominated a low voltage trip threshold setting of 180 volts.

Consultation with industry and peak bodies found no evidence of any practice where installers changed the under-voltage protection setting from the ‘out-of-the-box’ default setting (around 200 volts). In addition, it is considered highly unlikely that the network would experience low voltage conditions at the time embedded generators are operating.

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[17] Descheemaeker, J, Van Lumig, M, Influence of supply voltage on the performance of household appliances, CIRED, 2015.

On the basis of this consultation and advice, the likelihood of customers being impacted by nuisance inverter tripping is considered minimal. However, should this occur, an appropriate response in the first instance would be to adjust the inverter setting. The distributors support this view.

Distributors further advised that any installer who may have installed an inverter with a setting likely to cause nuisance tripping has not contravened any standard or connection requirement. As such, in the unlikely event a customer experiences nuisance tripping as a result of the proposed change to network voltage limits, customers would not be required to replace the inverter.

It should be noted that the estimated cost of adjusting the inverter setting ($200 to $300) is significantly less than the cost of replacing an inverter ($1500 to $2000). Given the limited likelihood of under voltage nuisance tripping occurring and that the number of customers potentially affected this circumstance is not known (and not ascertainable), the cost impacts are not included in the CBA.

4.4.5.3 Benefits – solar bonus scheme customers

Option 2 is expected to see customers on the Solar Bonus Scheme (SBS) export more self-generated electricity to the network (due to better energy efficiency) to the value of approximately $7 million over 10 years. The analysis assumes the premium feed-in-tariff (FiT) rate of 44 c/kWh with payments increasing in line with Figure 17. The benefit to SBS customers under Option 2 is recovered by distributors from the broader customer base through network tariffs.

4.4.5.4 Benefits – new solar PV customers[18]

Figure 18 shows an NPV benefit to new solar customers under Option 2 of approximately $42 million ($29 million for residential solar customers and $13 million for business solar customers). These benefits accrue from a greater ability to connect an exporting solar PV system to the grid, self-consume solar energy and receive FiT payments for excess solar generation exported back into the grid.

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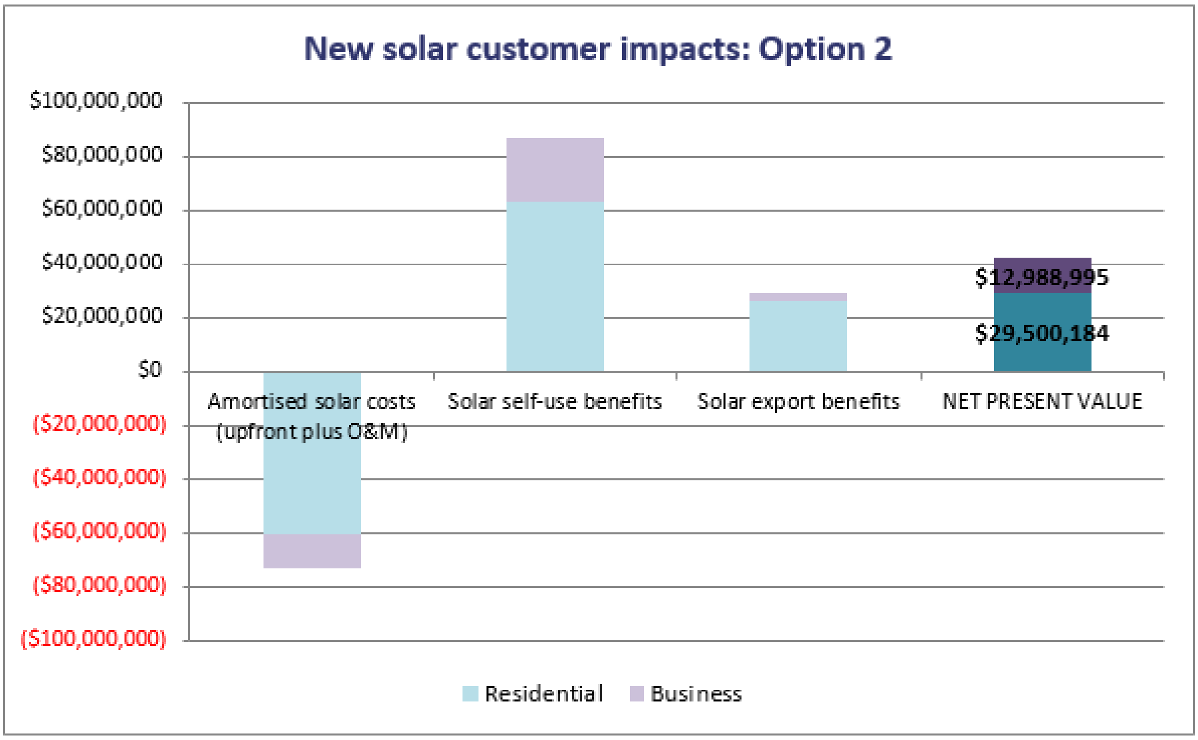
[18] For the purposes of this analysis, ‘new solar customers’ are considered to be residential and business customers who install a solar PV system after adoption of the new voltage supply and power quality standards in option 2.

Figure 18 – Option 2 new solar customer impacts



The costs and benefits of solar for new PV customers

The modelling assumes 8 per cent more rooftop PV capacity under Option 2, relative to the base case. Net benefits to solar PV customers consider the costs and benefits of solar PV over time. Assuming upfront purchase of the solar PV system, a standard cost benefit analysis over a 10-year period would capture all of the upfront costs and 10 years of benefits for Customer A who installs a solar PV system in year 0. For Customer B who installs solar PV in year nine however, it would capture all of the upfront costs but only one year (or 10%) of the benefits. For Customer B, the overall value of installing solar therefore appears as a *net cost*, rather than a net benefit. Table 6 illustrates this affect.

Table 6: relative benefits and costs captured under standard modelling approach

Standard approach: Benefits & Costs	Customer A	Customer B
Install year	Year 0	Year 9
Customer: benefits captured	100% (10 yrs)	10% (1 yr)
Customer: costs captured	100%	100%
Installer margin: benefits captured	100%	100%

The cost benefit analysis seeks to address this issue by weighting the cost and benefits for customers. For example, the estimated cost for Customer B who installs solar in year nine is weighted by 10 per cent to match the estimated benefits captured in the analysis. Table 7 outlines the relative weightings of costs and benefits captured under this alternative approach.

Table 7: relative benefits and costs captured under new modelling approach

Alternative approach: Benefits & Costs	Customer A	Customer B
Install year	Year 0	Year 9
Customer: benefits captured	100% (10 yrs)	10% (1 yr)
Customer: costs captured	100%	10%
Installer margin: benefits captured	100%	100%

Other impacted groups

The CBA also looks at the impact on solar installers from increased solar PV uptake. As the profit margin to solar installers is received upfront (determined as a percentage of the total installation costs), these groups have not been re-weighted.

With respect to solar PV uptake, the analysis assumes an 8 per cent increase across the network. This is based on expected improvements in solar PV hosting capacity, and the relaxation of technical assessment thresholds and conditions as advised by distributors (see qualitative impacts, page 22). Given the qualitative nature of the evidence underpinning this assumption, a sensitivity analysis considering zero and 25 per cent additional uptake scenarios was undertaken. The outcomes show a relatively low economic impact in both cases, with neither affecting the final recommendation of this RIS.

Benefits for residential and business customers who consume their own solar generation are estimated at $64 million and $24 million respectively. This assumes an average generation of 4.2 kWh/kW per day (the Queensland average) with 0.5 per cent degradation in solar energy output per year. For the purposes of this RIS, residential customers are considered to self-use 40 per cent of their solar generation and business customers 70 per cent, consistent with current distributor data.

With respect to solar export benefits, residential customers are expected to receive around $26 million in additional solar FiT payments and business customers approximately $3 million under Option 2. Benefits have been calculated using the 2016-17 regional FiT of 7.448 cents/kWh, with assumed exports of 60 per cent of generation for residential customers and 30 per cent for business customers. This is expected to contribute approximately 860GWh of avoided consumption to the reported total (2400GWh) over the next 10 years.

4.4.5.5 Costs – new solar PV customers

Residential and business customers are expected to spend approximately $60 million and $13 million respectively on new solar PV under Option 2. This assumes system costs of $1.50 per watt (including up-front and ongoing costs).

4.4.6 Option 2 impacts – other businesses[19]

Under Option 2, solar PV installers can expect a NPV benefit of approximately $9 million as a result of increased sales. The calculations assume an 8 per cent retail margin on all additional systems sold and increased solar PV uptake of 8 per cent on current levels for the reasons set out in section 4.4.1 (qualitative impacts, page 25).

Advice from electrical appliance and equipment manufacturers indicates that little (if any) equipment is currently manufactured to the Queensland voltage standard. As such, manufacturers are not expected to be impacted as a result of Option 2.

If the benefits captured by customers were to lead to increased sales of goods or services in other areas of the economy, there may be benefits to other businesses procuring increased sales revenue. However, for the purpose of this RIS, this flow-on impact has not been included.

4.4.7 Option 2 impacts – government

There is expected to be an overall reduction in goods and services tax (GST) revenue to the Federal Government due to avoided electricity consumption. However, it is expected that the benefits captured by customers would lead to increased tax revenue in other areas of the economy (due to customers spending electricity savings on other goods or services). Therefore, a neutral impact on GST revenue collected by the Federal Government is assumed.

The Queensland Government will be impacted indirectly through its ownership of electricity generators and of Energy Queensland. The overall impact on the government subsidised electricity Community Service Obligation (CSO) depends on how avoided DUOS costs flow through to Ergon Energy and Energex network costs. Where network price increases from the pass-through of avoided DUOS charges are higher in Ergon Energy's network than Energex's, the CSO paid by government

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[19] For the purposes of this RIS, other businesses include solar PV installers and electrical appliance manufacturers.

may increase (or vice versa if Ergon Energy's price increases are lower) and this will affect the overall net government impact.

An estimated 40MW of installed solar capacity from this option will contribute to the Queensland Government's one million solar rooftops or 3000MW of installed solar capacity by 2020 target and broader renewable energy policy objectives.

4.4.8 Option 2 impacts - environmental

No economic value has been attributed to environmental impacts for the purpose of the CBA. However, it is estimated that Option 2 could avoid around 1.7 million tonnes of carbon emissions (tCO2-e) over 10 years. This calculation is based on an average grid emissions factor of 0.70 kg CO2-e/kWh. The 2016 National Greenhouse Account Factors report current Queensland grid electricity factor of 0.79 kg CO2-e/kWh. The analysis assumes a decline in the Queensland emissions factor over the next 10 years as more renewables make up a larger proportion of grid energy mix. An estimated emissions factor of 0.70 over 10 years is applied.

4.5 Option 3 – adopt the national standards for voltage and power quality with a 3-year transition to full compliance with power quality requirements

Under Option 3, Queensland adopts the voltage limits and network power quality measures set out in AS60038 and AS61000.3.100. Distributors have a one-year transition period to comply with AS60038 and three years to comply with AS61000.3.100 requirements (Option 2 proposed 'BAU' implementation over seven years).

The accelerated timeframe of Option 3 necessitates a dedicated compliance work program and therefore implementation costs for Option 3 are higher than Option 2. However, as Option 3 is implemented faster than Option 2, it allows greater amounts of renewable and embedded generation to be integrated earlier than Option 2. This is important as it brings forward benefits such as increased network solar hosting capacity and more flexible connection requirements for customers in time to support government's 2020 solar targets. It helps the state prepare early for our renewable energy future. As a flow on effect, Option 3 also brings forward environmental and solar industry benefits compared with Option 2.

The risk to customers of appliance failure/damage from high voltage also reduces more quickly under Option 3, as does the risk of household solar PV automatically disconnecting from the network to protect itself in times of high voltage. Critically, Option 3 more quickly reduces the risk to customers of fire from overheating appliances in extreme circumstances where voltage levels are well above the median.

Figure 20 sets out the quantifiable costs and benefits of Option 3 for stakeholder groups. The total NPV benefit under Option 3 is approximately $256 million on the base case, approximately $41 million greater than Option 2 (Figure 21). This is primarily because energy efficiency benefits are captured earlier and are therefore higher under Option 3.

For these reasons, Option 3 is the recommended approach.

Figure 20 – Option 3 overall impacts

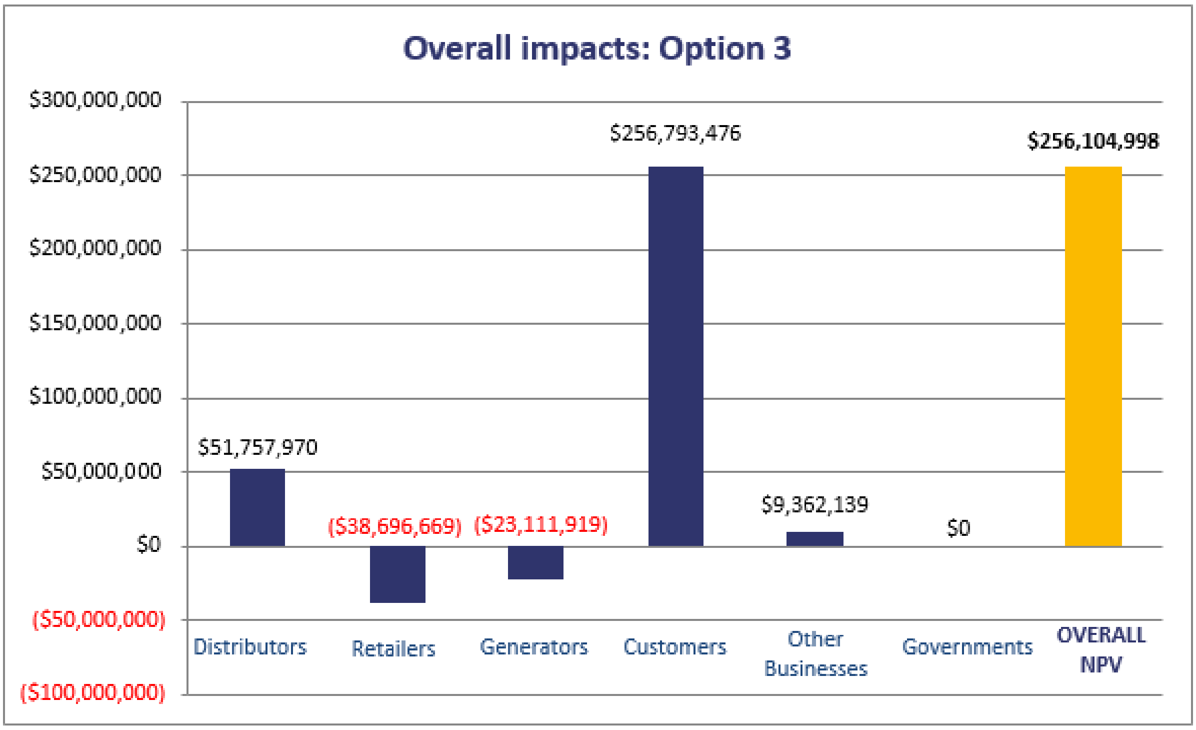
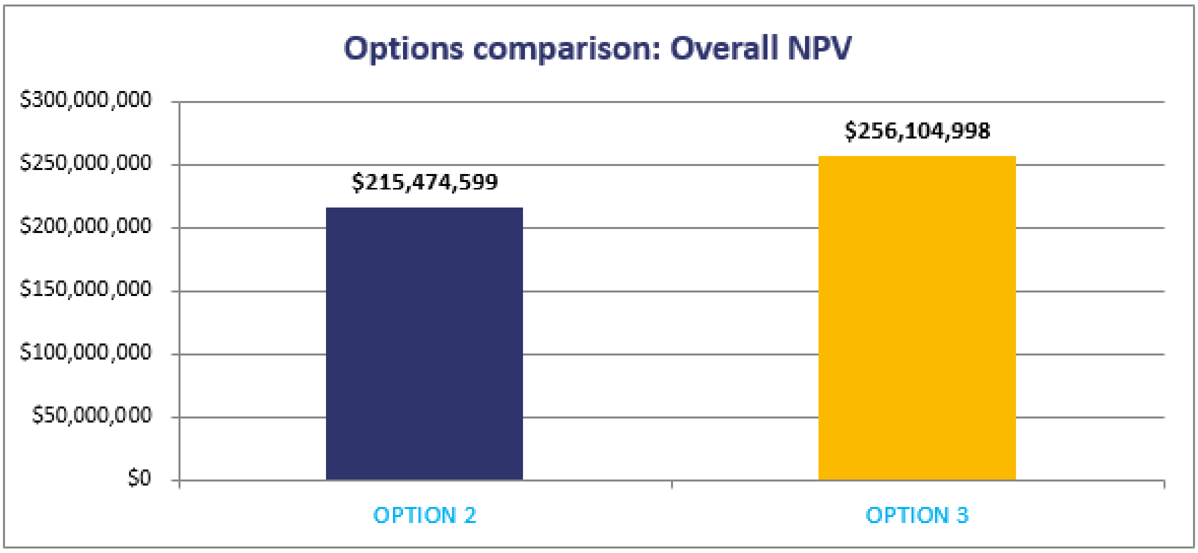


Figure 21 – Overall NPV comparison



4.5.1 Option 3 – comparative analysis (Part 1)

The presentation of analysis for Option 3 is divided into two parts:

- Part 1, set out in Table 8, summarises the common stakeholder benefits, costs (and assumptions) between Options 3 and 2, relative to the base case.
- Part 2 describes in detail the additional quantifiable benefits and costs of Option 3 compared to Option 2.

Table 8 – Summary of common costs, benefits and assumptions – Options 2 and 3

Comparative Analysis (Part 1): summary of common costs, benefits and assumptions - Options 2 and 3		
Stakeholder Group	**Stakeholder costs and benefits**	**Assumptions**
Distributors	*Customer complaint benefits:* Ergon Energy: **\$2.5million** Energex: **\$2.5 million** Total: **\$5 million**	40% reduction in customer high voltage complaints.
	Augmentation benefits: Ergon Energy: **\$35 million** Energex: **\$20 million** Total: **\$55 million**	Based on BAU cost data provided by distributors.
	Industry communications and training material costs: Ergon Energy: **\$500,000** Energex: **\$500,000** Total: **\$1 million**	
Electricity customers	*Network augmentation savings (2020 to 2025):* Residential: **\$10 million** Business: **\$6 million** Total: **\$16 million**	Distributors' network augmentation costs will be lower than they would otherwise be in their pricing proposal for the 2020-25 regulatory period.
	Extended product life benefit: All customers: **\$4 million**	Electrical appliances and equipment will operate closer to the mid-range of their operating parameters.
New solar customers	*New solar NPV benefit:* Residential: **\$29 million** Business: **\$13 million** Total: **\$42 million**	8 per cent additional solar PV capacity installed.

	Solar self-use benefits: Residential: **$64 million** Business: **$24 million** Total: **$87 million**	Solar self-use 40 per cent and 70 per cent for residential and business customers respectively. Average generation of 4.2 kWh/kW per day with 0.5 per cent degradation in output per year.
	Solar export benefits: Residential: **$26 million** Business: **$3 million** Total: **$29 million**	Solar exports of 60 per cent of generation for residential customers and 30 per cent business customers paid at the regional FiT rate (7.448 cents/kWh).
	Solar PV system costs (installation and ongoing maintenance: Residential: **$60 million** Business: **$13 million** Total: **$73 million**	New solar PV system costs $1.50 per watt (includes up-front and ongoing costs).
Other businesses	_NPV benefit:_ Solar PV installers: **$9 million**	8 per cent more systems installed at 8 per cent retail margin
Queensland Government	There are potential indirect financial costs, but these are but unable to be quantified.	The Queensland Government will be impacted indirectly through its ownership of electricity generators and of Energy Queensland. Potential impact on the government subsidised electricity CSO depends on how avoided DUOS costs flow through to Ergon Energy and Energex network charges, and are therefore unable to be quantified in the analysis. 40MW of installed solar capacity will support solar and renewable energy targets and policy objectives.

4.5.1.1 Grid energy use assumptions

Assumptions in relation to reduced grid energy use are the same for Options 2 and 3 (Table 6).

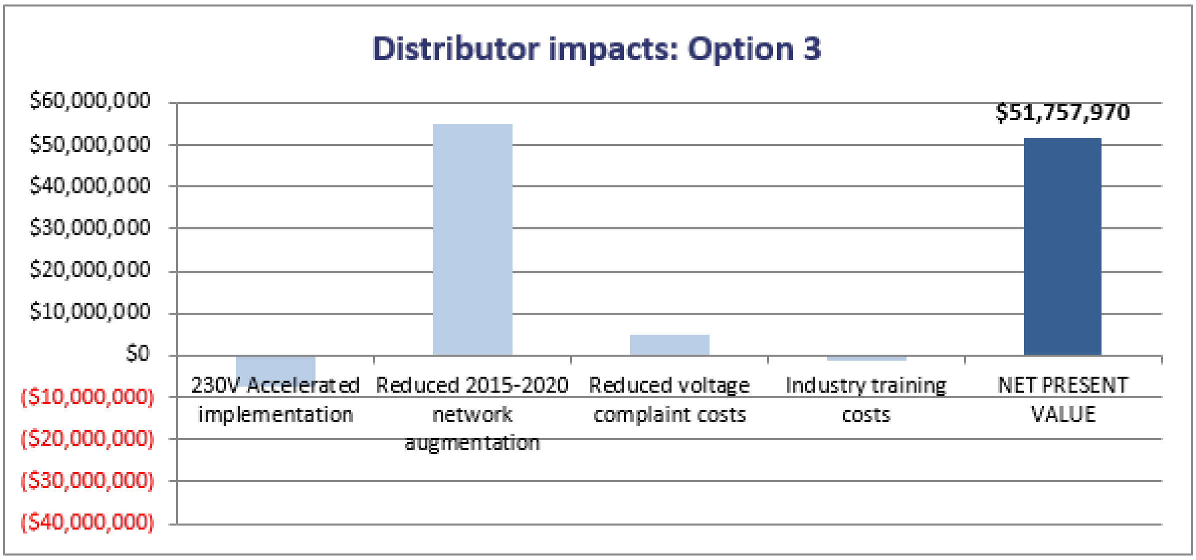
4.5.2 Option 3 – comparative analysis (Part 2)

The following section compares the differences between Option 3 and Option 2 against the base case. A key difference in this analysis is the assumption that implementation is accelerated which leads to the accelerated realisation of multiple benefits, including energy efficiency benefits of 0.65 per cent which are realised over three years instead of seven years.

4.5.2.1 Option 3 – differences in network impacts

The total NPV benefit on the base case for distributors under Option 3 is approximately $52 million as a result of reduced network augmentation expenditure and reduced expenditure in dealing with customer voltage complaints (Figure 22). This is $7 million less than the NPV benefit to distributors in Option 2.

Figure 22 – Option 3 network impacts



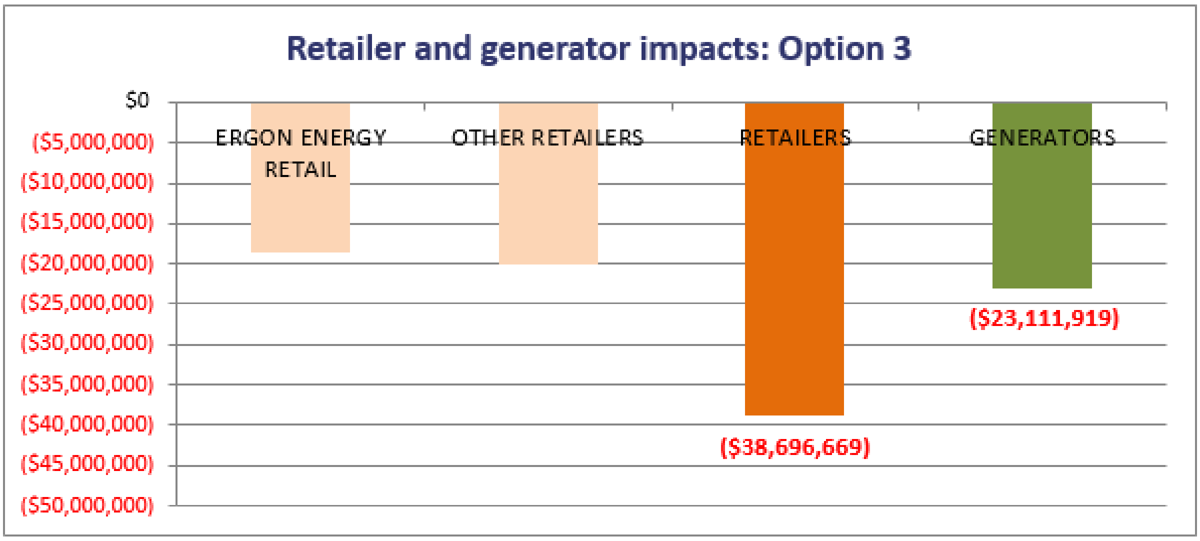
$7 million represents the cost to distributors of a dedicated work program to implement new requirements within three years ($6 million and $1 million for Energex and Ergon Energy respectively). Ergon Energy’s costs are lower as network supply voltage can be lowered more efficiently at the zone substation level. Energex costs are based on manually changing voltage settings at the transformer level, a more labour (and therefore cost) intensive process.

In its submission to the Consultation RIS, AGL questioned whether the distributors would forgo other business priorities in order to meet the accelerated implementation proposed under Option 3. Initial advice indicated that Option 3 may impact the current program of works for both Energex and Ergon Energy due to resource limitations. However, subsequent advice from the distributors favoured the earliest possible deployment of the proposed voltage standards and a willingness to work with DEWS to effectively transition to the 230 volt standard.

4.5.2.2 Option 3 – differences in retailer and generator impacts

Electricity retailers and generators will incur a total NPV cost of approximately $62 million under Option 3 (Figure 23). This includes lost retailer revenue of approximately $39 million with Ergon Energy Retail incurring $19 million and SEQ retailers $20 million due to lower energy consumption. Similarly, generators are expected to incur a net loss of approximately $23 million. Total lost retail and generation revenue is $12 million higher under Option 3 than Option 2.

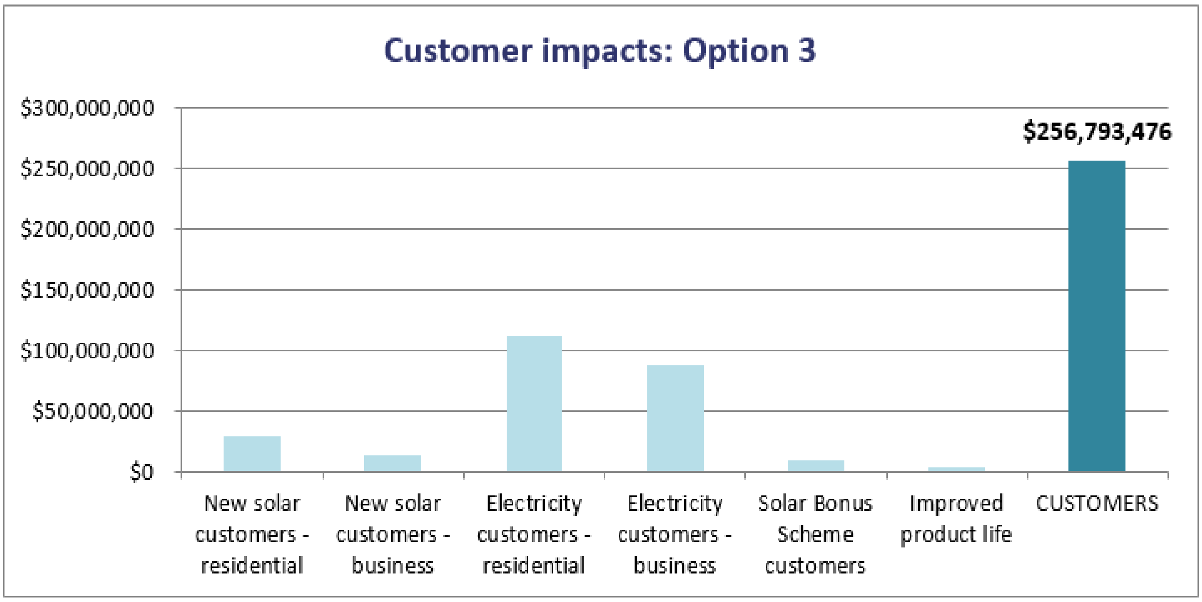
Figure 23 – Option 3 retailer and generator impacts



4.5.2.3 Option 3 – differences in overall customer impacts

The NPV benefit to customers under Option 3 is approximately $257 million (Figure 24). This is an increase on Option 2 of approximately $59 million.

Figure 24 – Option 3 customer impacts



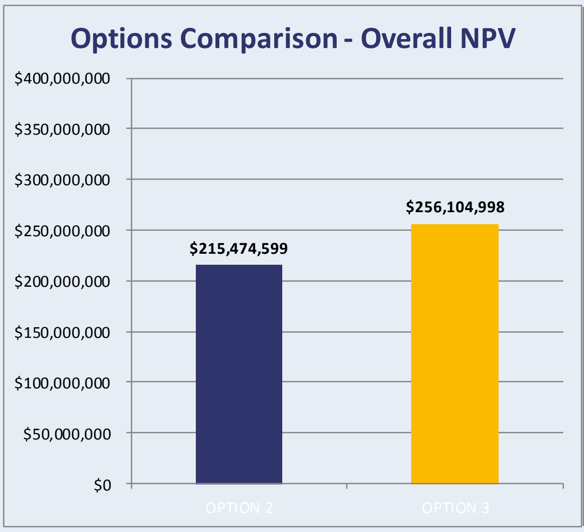
Energy Efficiency Sensitivity

When voltage reduces, some appliances (constant loads) experience no reduction in energy consumption, while some appliances (resistive loads) experience some reduction in energy consumption due to reduced heat loss. Previous studies have estimated the relationship between voltage reduction and consumption reduction, also known as the Conservation Voltage Reduction (CVR) factor. A CVR trial by Ausgrid and the Federal Department of Industry, Innovation and Science[21] showed that for a 1 per cent reduction in voltage, grid consumption is expected to reduce by 0.65 per cent.

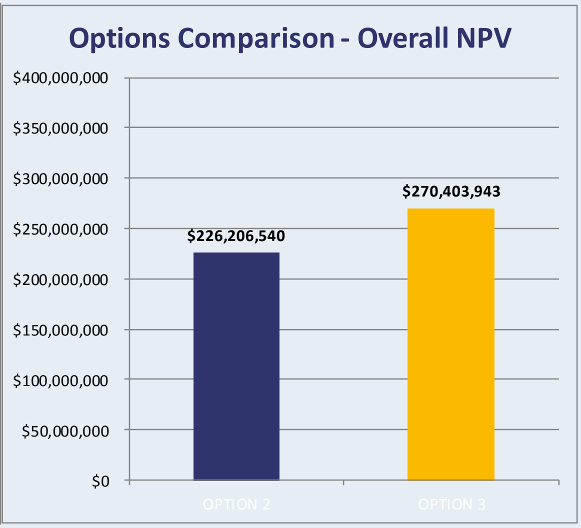
The RIS CBA uses 0.65 per cent as the estimate for energy efficiency improvements should the proposed voltage and power quality standards be adopted in Queensland. Noting that a reduction in median network voltage supply from 240V to a 234.5V is greater than 2 per cent, the 0.65 per cent ‘CVR factor’ applied in this analysis is considered conservative.

Energex[22] notes that the IEEE Power and Energy Society found CVR factors to be in the range of 0.70 to 1.00. A sensitivity analysis has been run using these estimates, as well as a ‘low case’ scenario of 0.10 per cent. The overall NPV outcomes for Options 2 and 3 have been tested under this range. In all cases, the CBA results in a higher overall NPV under Option 3.

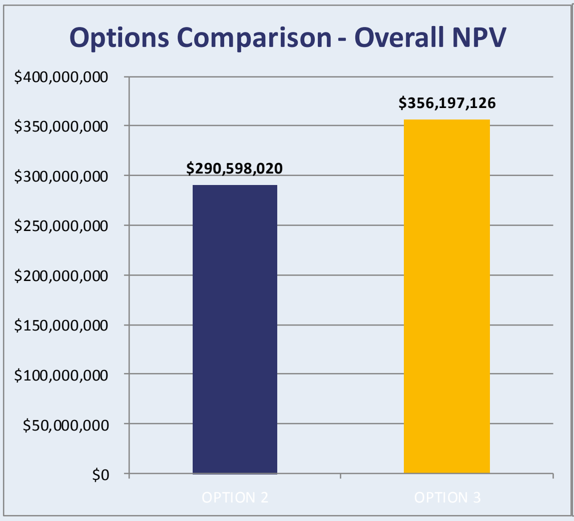
0.65% energy reduction



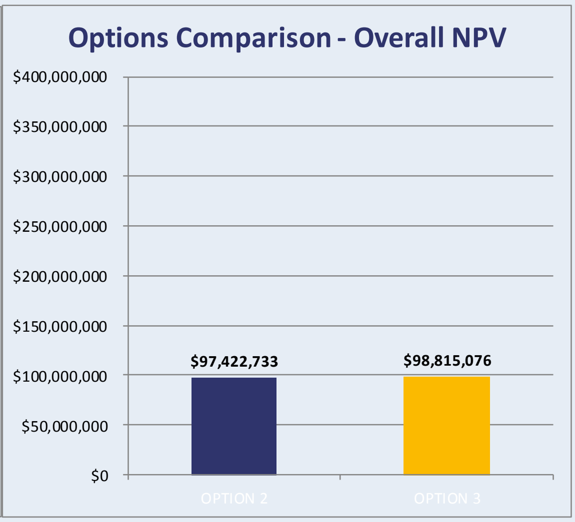
0.70% energy reduction



1.00% energy reduction



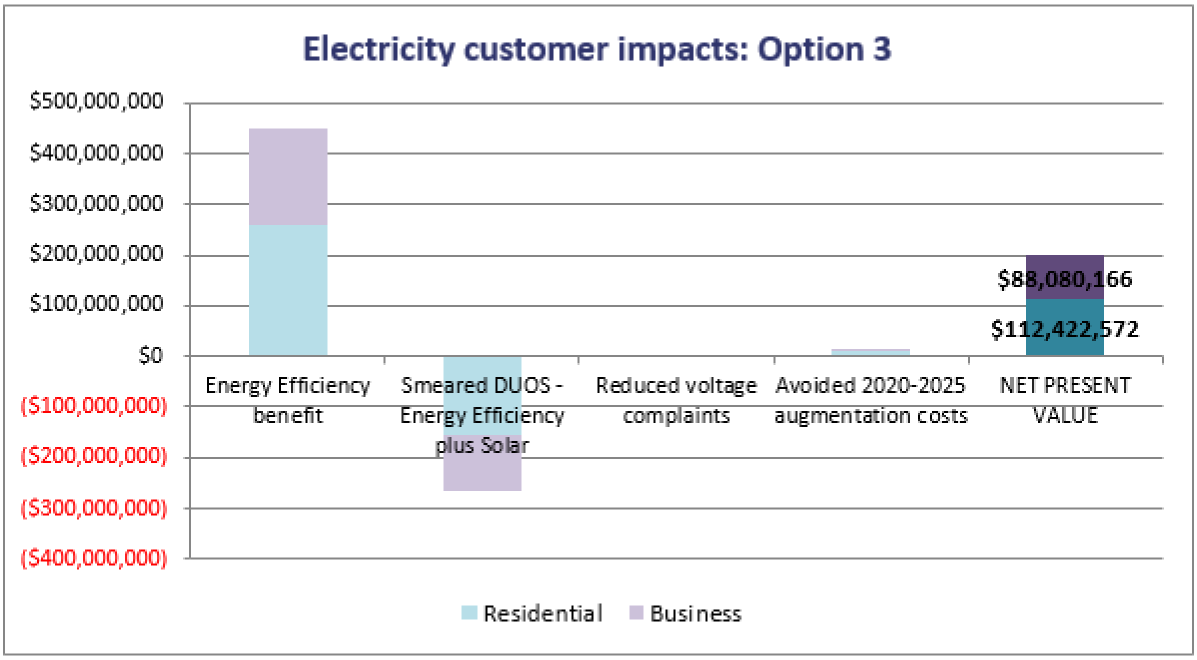
0.10% energy reduction



4.5.2.4 Option 3 – differences in electricity customer benefits

Figure 25 shows the total NPV benefit for electricity customers under this approach is approximately $200 million (including $112 million for residential customers and $88 million for business customers), around $56 million more than Option 2. This equates to a saving per household over 10 years of approximately $55 – $15 more than Option 2. For businesses the saving is around $400 over 10 years, $100 higher than Option 2.

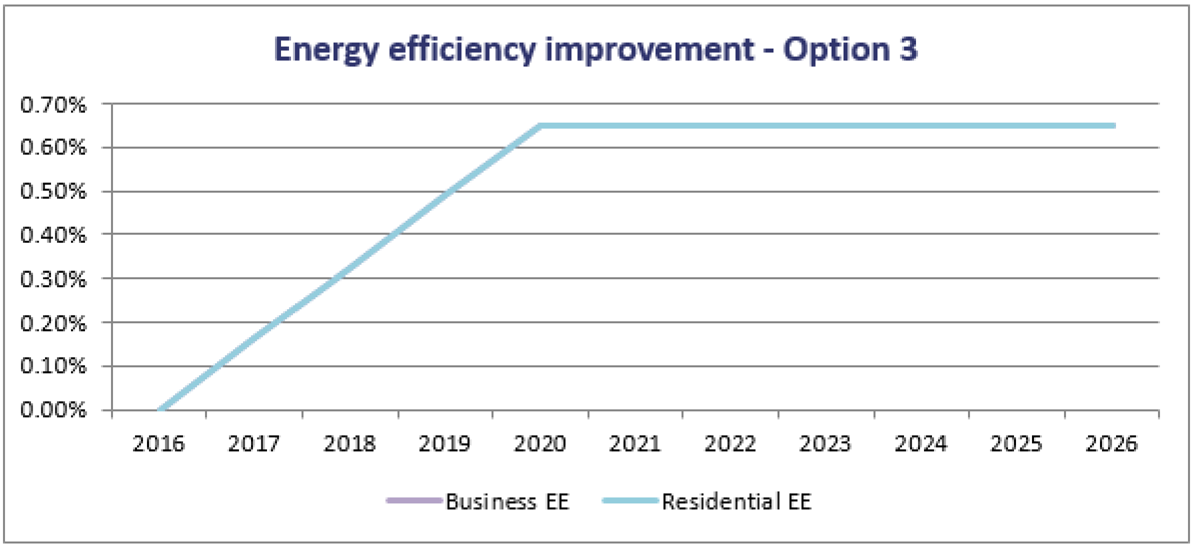
Figure 25 – Option 3 electricity customer benefits



Under Option 3, customers will avoid approximately $450 million in electricity consumption costs as a result of improved energy efficiency ($260 million for residential customers and $190 million for business customers). This is an increase of $113 million compared to Option 2.

As noted above, the proposed three-year implementation timeframe for Option 3 will see customer energy efficiency benefits achieved faster than under Option 2, leading to 1990GWh in avoided consumption (Figure 26). This means 450GWh less electricity will be consumed over 10 years under Option 3 than Option 2 (a total of 2850GWh is avoided under Option 3 including solar impacts).

Figure 26 – Option 3 energy efficiency improvement



The impact on Solar Bonus Scheme (SBS) costs is also expected to be greater under Option 3 than under Option 2 with SBS customers expected to be better off by $10 million compared to the base case. This is around $3 million greater than Option 2.

4.5.2.5 Option 3 – differences in electricity customer costs

Under Option 3, distributors will look to recover approximately $265 million of avoided DUOS charges from electricity customers ($156 million for residential customers and $109 million for business customers), $57 million more than under Option 2.

4.5.2.6 Option 3 – differences in environmental impacts

Carbon equivalent emission reductions of 2 million tCO_2-e over 10 years are expected under Option 3, an increase of 300,000 tCO_2-e compared to Option 2.

5. Consultation

A wide range of stakeholders and interested parties were identified and consulted as part of this work. Around 20 face-to-face and telephone interviews were held with industry experts, customer groups, equipment manufacturers and groups representing the electrical contracting industry during preparation of the Consultation RIS.

Interviews and desktop reviews of available reports and information were undertaken, to ensure:

- all reasonable options were considered
- impacted stakeholders were identified and consulted
- the expected advantages of the policy change were real and able to be realised
- costs of the proposed change were identified

- impacts to stakeholders were identified and understood
- risks of the change were assessed, with mitigation strategies identified.

The consultation process targeted three objectives:

1. To ascertain support or otherwise from experts in the field, and identify any risks or costs.
2. To assess the risk that the lower voltage permitted under the uniform standard may present to electrical equipment or customer appliances.
3. To understand the experiences of other jurisdictions who have undertaken the change to the uniform standard in recent times (e.g. since 2000).

The consultation undertaken in this process identified the following common themes:

1. New South Wales and South Australia implemented the change to the uniform standard from 2000. Very few comments or concerns were received, and the number of complaints of high network voltage reduced significantly in both cases.
2. All appliance and equipment manufacturers noted that their equipment has been built to the uniform voltage standard for all of Australia for some years.
3. Subject experts are largely supportive of adopting the change to the uniform standard, with some minor unquantified concern for older equipment that may not operate properly in rare times of lowest permitted voltage.
4. A strong desire for effective communication of any changes to electricians and related sectors.

In developing this Decision RIS, DEWS called for submissions from interested stakeholders with 116 individuals and organisations responding as part of this process. DEWS reviewed all submissions and incorporated feedback into the discussion and analysis where appropriate.

6. Conclusion and recommended option

Based on the available evidence, DEWS concludes that accelerated adoption of the uniform standard for network voltage (AS60038) and the statistical assessment of steady-state electricity supply conditions (AS61000.3.100) will bring forward more efficient, best practice management of Queensland electricity networks as well as the integration of additional renewable energy generation in Queensland, with the greatest net benefit to customers, industry and Queensland Government policy objectives.

As such, it is recommended that Queensland proceed with the approach to adopt Option 3 (as set out in this this document).

7. Consistency with fundamental legislative principles

The regulatory amendments proposed under the recommended option (Option 3) are consistent with fundamental legislative principles as defined under Section 4 of the *Legislative Standards Act 1992*.

As per Section 7 of the *Legislative Standards Act 1992*, the Department of Energy and Water Supply will seek advice on the application of fundamental legislative principles from the Office of the Queensland Parliamentary Counsel should the proposal progress to the regulatory drafting stage.

8. Implementation, compliance support and evaluation strategy

8.1. Transitional period for compliance

Consideration will be given to a one-year transition to the uniform standard for network voltage (AS60038) and three years for the statistical assessment of steady-state electricity supply conditions (AS61000.3.100). This transitional period is firstly to permit any contracts or agreements that may be in place to be identified and modified. Secondly, it gives distributors the opportunity to identify and lower supply voltage on sections of the network at higher risk of operating above the proposed new ‘ceiling’ which is 1.4 volts lower than the current requirement. Finally, utilities will need to review and update design standards and field commissioning practices. The transition period will permit time for these changes to be enacted.

8.2. How would the change be communicated?

Communication of the change would be made through:

- an information forum held by government with a wide range of stakeholders as invitees. The forum would explain the background of the change, its intended purpose, and implementation measures taken
- advice to all licensed electrical contractors in Queensland through the services of the Electrical Safety Office newsletter facility
- advertising through industry groups and appliance manufacturers
- direct email to all stakeholders who take part in the Regulatory change process
- advice to Queensland’s electricity distributors, generators, retailers.

8.3. Performance monitoring

During the implementation period, the government will continue to work with distributors to monitor the progress of identified project outcomes. Specifically, the government will seek data and updates from distributors regarding:

- BAU monitoring of voltage complaints and the cost of response
- BAU monitoring of solar PV installations
- progress of transition to the new requirements
- changes to technical requirements, including assessment thresholds, in the connection standard for small-scale embedded generators up to 30kVA.

9. List of abbreviations

Abbreviation	Term
ADMA	After diversity maximum demand
AER	Australian Energy Regulator
AS	Australian Standard
BAU	Business as usual
CBA	Cost benefit analysis
COAG	Council of Australian Governments
COAG Energy Council	Council of Australian Governments’ Energy Council
CPI	Consumer price index
CSO	Community service obligation
CVR	Conservation voltage reduction (factor)
c/kWh	Cents per kilowatt hour
DEWS	Queensland Department of Energy and Water Supply
Distributors	Energex and Ergon Energy (Queensland’s energy distribution companies)
DUOS	Distribution use of service (charges)
FiT	Feed-in tariff
GST	Goods and services tax
GW	Gigawatt(s)
GWh	Gigawatt hour(s)
IEC	International Electrotechnical Commission
kgCO2e	Kilogram(s) of carbon dioxide equivalent
kVa	Kilovolt ampere(s)
kW	Kilowatt(s)
kWh	Kilowatt hour(s)
MW	Megawatt(s)
MWh	Megawatt hour(s)
NEM	National Energy Market
NER	National Energy Rules
NPV	Net present value
PV	Photovoltaic
QCA	Queensland Competition Authority
QLD	Queensland
RIS	Regulatory impact statement
SEQ	South-East Queensland
Tariff 11	Ergon Energy small customer flat rate residential tariff
Tariff 20	Ergon Energy small customer flat rate business tariff
TCA	The Customer Advocate
tCO2e	Tonne(s) of carbon dioxide equivalent
UTP	Uniform tariff policy
V	Volt(s)
WACC	Weighted average cost of capital