Business Case
Power Quality

Executive Summary

Energex has installed approximately 22,000 Power Quality monitors over the current and previous regulatory control periods with a successful quality of supply outcomes for both the network and the customers. Energex PQ monitors are connected to the low voltage (LV) terminals of the distribution transformer and provide a reflection of the medium voltage network including the PQ parameters. The installed PQ monitors have provided a real-time response on the state of the network in areas where no other measurements are available, and PQ Monitors are the primary source to report on compliance for 230V standard throughout the Energex network.

Increasing uptake of sensitive electronic equipment, various forms of disturbing loads, and embedded generation systems such as Solar Photovoltaics (PV) by customers within the Energex network is having significant impacts on network Power Quality (PQ) parameters and customer quality of supply within low voltage networks. Energex aspires to continue to deliver and improve upon the existing Power Quality performance despite rapidly changing patterns of behaviour, meeting customer expectations associated with a modern electricity grid and allowing customers to reap the benefits of distributed generation.

This business case seeks an extension of the existing regulatory control period 2015-20 program of works, which broadly includes an extension of PQ monitoring and analytics capability, customer voltage remediation works in low voltage (LV) and medium voltage (MV) networks, and augmentation works required to allow bidirectional power flow and rectify power quality issues due to emerging solar PV constraints in LV networks. The AER, in the draft distribution determination, have already recognised and accepted that Energex's expenditure proposal with regards to reactive management of existing and future PQ issues (caused by solar PV) and customer voltage remediation works as prudent and efficient.

Three options were evaluated as part of this business case:

Option 1 – A counterfactual, 'do nothing' option under which no works are performed to improve Power Quality monitoring.

Option 2 – Solar PV augmentation works will be performed during the 2020-25 regulatory period in order to maintain compliance with relevant safety and performance standards.

Option 3 – Extension and upgrade of the existing PQ Monitoring capability in the Energex network, by connecting PQ monitors to a further 8% of distribution feeders. This option includes the augmentation works proposed under Option 2.

Energex aims to minimise expenditure in order to keep pressure off customer prices, however understands that this must be balanced against critical network performance objectives. These include network risk mitigation (e.g. safety, bushfire), regulatory obligations (e.g. safety), customer reliability and security and preparing the network for the ongoing adoption of new technology by customers (e.g. solar PV). In this business case both reliability and supporting the adoption of new technology by customers are strong drivers, based on the need to improve Power Quality monitoring and analytics capabilities to assist Energex with managing the ongoing uptake of solar PV systems by customers.

To this end, Option 3 is the preferred option. It provides the most cost-effective means of addressing the need for solar PV augmentation works and increased Power Quality monitoring, with a Net Present Value (NPV) result of -$38.2M. It is important to note that when considered separately, the expansion of Power Quality monitoring under Option 3 is NPV positive, delivering an NPV result of $1.4M.

The direct cost of the program for each submission made to the AER is summarised in the table below. Note that all figures are expressed in 2018/19 dollars and apply only to costs incurred within the 2020-25 regulatory period for the preferred option.

Regulatory Proposal	Draft Determination Allowance	Revised Regulatory Proposal
$44.1M	$0	$42.9M

The preferred option also supports the recommendations from the Australian Energy Market Commission (AEMC) to the DNSPs to continue improving modelling and visibility of their LV networks in the authority's review paper titled "Integrating DERs for the Grid of the Future", published in September 2019.

The program presents customer benefits by enhancing quality of service through improved network visibility and the move to a more reactive response model. Issues associated with solar PV curtailment, potential equipment damage, and PQ issues such as noise are expected to be reduced through the program, despite rapidly changing patterns of behaviour. The extended PQ monitoring capability is expected to reduce the cost of QoS enquiries, processing of connection applications, and investment into network augmentation works, by reducing the need for manual data collection and improving Energex's understanding of the causes and effects of PQ problems.

Finally, this program assists Energex in a transition to the intelligent grid of the future. Beyond 2020, together with other initiatives, the PQ monitoring program will enable application of intelligent grid solutions (including planning and management of micro-grids), development of technology platforms for monitoring and analysing of distributed energy resources and support future PQ initiatives on LV networks.

Contents

1 Introduction

Energex's Power Quality (PQ) strategic proposal for the regulatory control period 2020/21-2024/25 is targeted at monitoring and managing both network and customer issues regarding power quality. This expenditure proposal seeks an extension of the existing regulatory control period 2015-20 program of works, which broadly includes PQ monitoring and analytics, identification and rectification of PQ issues, and management of the low voltage (LV) and medium voltage (MV) networks. It also covers the specification of expenditure relating to works required to allow bidirectional power flow and rectify power quality issues due to emerging solar PV constraints in LV networks.

1.1 Purpose of document

This document recommends the optimal capital investment necessary for the Energex Power Quality Program. This is a preliminary business case document and has been developed for the purposes of seeking funding for the required investment in coordination with the Energex Revised Regulatory Proposal to the Australian Energy Regulator (AER) for the 2020-25 regulatory control period. Prior to investment, further detail will be assessed in accordance with the established Energy Queensland investment governance processes. The costs presented are in $2018/19 direct dollars.

1.2 Scope of document

The scope of this proposal is for Power Quality programs which are targeted at both the LV and MV networks. The programs are primarily based on the current regulatory requirement to maintain statutory voltages within the range 230 V +10/-6% and will mainly address the worst areas emerging from the growth of emerging technologies (Electric Vehicles (EV), Solar PV, storage batteries, and sensitive appliances) connected on the network.

This program also focuses on identifying non-compliant areas of the network with respect to statutory voltages and other network PQ parameter standards, to develop and implement a targeted program of prioritised remediation works that will reduce non-compliance over the next regulatory period.

This strategic proposal covers expenditure for programs in three categories:

1. Power Quality Monitoring;
2. Customer voltage remediation works; and,
3. Solar PV related augmentation works.

1.3 Identified Need

Energex aims to minimise expenditure in order to keep pressure off customer prices, however understands that this must be balanced against critical network performance objectives. These include network risk mitigation (e.g. safety, bushfire), regulatory obligations (e.g. safety), customer reliability and security and preparing the network for the ongoing adoption of new technology by customers (e.g. solar PV). In this business case both reliability and supporting the adoption of new technology by customers are strong drivers, based on the need to improve Power Quality monitoring and analytics capabilities to assist Energex with managing the ongoing uptake of solar PV systems by customers.

Power Quality issues are becoming more prominent in the Energex network as uptake of sensitive electronic equipment, various forms of disturbing loads, and embedded generation systems accelerates. In response to customer engagement, Energy Queensland (EQL) has developed two complementary strategies to manage typical network Power Quality parameters such as overvoltage, under-voltage, sags, swells, flickers, imbalance and harmonics. These strategies, the Customer Quality of Supply Strategy and the Low Voltage Monitoring Strategy (henceforth referred to as the Power Quality Strategies), set out the requirements to deliver an improved network monitoring system, capable of:

- Reporting on the state of the network for all the Power Quality parameters;
- Assisting in remediation works necessary to improve Power Quality outcomes; and,
- Assisting in the decision making for network augmentation work and connection of new customers to meet Power Quality standards and targets.

These strategies also address the network PQ obligations, drivers and future requirements, with a major focus on voltage management on all parts of the network. Power Quality performance monitoring and improvement works are also envisaged to drive prudent and efficient investments on network augmentation.

As part of previous Power Quality programs, over 22,000 PQ monitors have been installed across the Energex network, providing coverage of around 44% of distribution transformers in the network. These assets have already delivered significant benefits to Energex; however, additional PQ monitoring devices and augmentation works are required to ensure compliance and deliver additional benefits across the network. This program represents an extension of previous PQ programs, in response to the need for continued expansion of current programs such as Power Quality monitoring, and the need for additional augmentation or remediation works to respond to particular PQ issues identified.

The need to extend the PQ monitoring program aligns with internal Energy Queensland strategies including the Power Quality Strategies, the Future Grid Roadmap, and the Intelligent Grid Technology Plan, as well as external strategies and aims for Queensland electricity networks:

- **Customer engagement programs:** EQL customer engagement programs indicate that customers are in favour of investments which make the grid ‘smarter’ and allow for use of more modern technologies. Customers with Distributed Energy Resources (DERs) want to gain the greatest economic benefit out of their assets without disruption to normal supply. The program will allow EQL to better understand the impact of DERs and changing patterns of customer activity on QoS, and plan works and regulations accordingly to maximise the benefit of these assets.
- **Leading industry knowledge:** The AEMC recently published a review paper titled “Integrating DERs for the Grid of the Future”, which highlights the need for Distribution Network Service Providers (DNSPs) to continue to develop business cases for improvement of modelling and monitoring of their LV networks, particularly in response to challenges caused by the rapid uptake of Solar PV. This program responds to this need by expanding Energex’s LV and MV monitoring capacity and acknowledges EQL’s involvement in research programs for alternative monitoring solutions such as use of smart-meters as well of the current limitations of these solutions.
- **Government policy:** The Powering Queensland Plan developed by the Department of Natural Resources, Mines and Energy sets out a target of 50% renewable energy supply by 2030. This program will help EQL optimise the uptake and operation of DERs into LV and MV networks, ensuring that uptake is not hampered by voltage or QoS issues and that where possible, network augmentation and investment can be limited by smart application of DERs.

The program is expected to deliver the following customer outcomes:

- **Driving Prudent Investment:** Power Quality data from a network of PQ monitors can be used to target prudent network augmentation. Where there are no PQ monitors, augmentation projects rely on network modelling data and short-term recordings in limited locations. Actual metered PQ data will allow validation of network modelling outcomes that will lead to increased confidence in augmentation investment decision making and over time will lead to improved accuracy of network models. The additional PQ data will ensure that the investments are applied to address confirmed existing and emerging capacity constraints.

- **Ensuring Customer Benefits and Intelligent Grid Outcomes:** The rationale of the PQ monitoring and augmentation program is to allow, where possible, all customers benefit from being able to draw load or generate into the network while also ensuring that the network conforms to all power quality parameters and relevant standards.
- **Improving Safety Outcomes:** Energex needs to be able to proactively identify, investigate and rectify any PQ related customer/network issues or non-compliance with the relevant standards. With increased monitoring of PQ parameters, the likelihood of damage to customer or network equipment from exposure to very high or otherwise unregulated voltage will be reduced, and the safety outcomes will improve for staff and customers who could otherwise be exposed to unregulated voltages.

This proposal aligns with the CAPEX objectives and criteria from the National Electricity Rules as detailed in Appendix C.

1.4 Energy Queensland Strategic Alignment

Table 1 details how the PQ program contributes to Energy Queensland's corporate and asset management objectives. The linkages between these Asset Management Objectives and EQL's Corporate Objectives are shown in Appendix D.

Table 1: Program Objectives and Strategic Alignment

Objectives	Relationship of Initiative to Objectives
Ensure network safety for staff contractors and the community	Effective monitoring of the LV and MV networks and a proactive response model will allow Energex to investigate and address issues before potential equipment damage occurs, safety is impacted, or customers become aware of the issue.
Meet customer and stakeholder expectations	Effective monitoring will reduce the number of Quality of Service enquiries and call-outs, and ensure the network is operating within all PQ standards. Additionally, this program responds to customer engagement programs which indicate customer enthusiasm for programs which help to deliver modern grid solutions. Improved LV network monitoring capability together with other initiatives, will enable application of intelligent grid solutions (including planning and management of micro-grids), and development of technology platforms for monitoring and analysing of DERs.
Manage risk, performance standards and asset investments to deliver balanced commercial outcomes	This program builds on benefits realised from previous PQ works, extending network functionality to increase Energex's ability to monitor and report on all parts of the network. Increased access to real-time data on PQ parameters also helps to inform efficient investment into remediation or augmentation works necessary to improve PQ outcomes, and allows Energex to take a balanced approach to investment and asset management.

Objectives	Relationship of Initiative to Objectives
Develop Asset Management capability & align practices to the global standard (ISO55000)	This approach is consistent with ISO55000 objectives and drives asset management capability by promoting a continuous improvement environment. Confidence in the information is improved to enable better reporting on the state of the network PQ parameters in documents such as the Distribution Annual Planning Reports (DAPR).
Modernise the network and facilitate access to innovative energy technologies	This approach promotes the use of developing technologies to improve customer outcomes, drive efficient investment, and allow increasing uptake of innovative energy technologies by customers across the Energex network in a manner that does not impact compliance or performance. Beyond 2020, together with other initiatives, the PQ Monitoring Program will enable application of intelligent grid solutions (including planning and management of micro-grids), development of technology platforms for monitoring and analysis of distributed energy resources and support future PQ initiatives on South East QLD LV networks.

1.5 Applicable service levels

Corporate performance outcomes for the network are rolled up into Asset Safety & Performance group objectives, principally the following Key Result Areas (KRA):

- Customer Index, relating to Customer satisfaction with respect to delivery of expected services.
- Optimise investments to deliver affordable & sustainable asset solutions for our customers and communities.

Corporate Policies relating to establishing the desired level of service are detailed in Appendix D.

Under the Distribution Authorities, EQL is expected to operate with an 'economic' customer value-based approach to reliability, with "Safety Net measures" for extreme circumstances. Safety Net measures are intended to mitigate against the risk of low probability vs high consequence network outages. Safety Net targets are described in terms of the number of times a benchmark volume of energy is undelivered for more than a specific time period. EQL is expected to employ all reasonable measures to ensure it does not exceed minimum service standards (MSS) for reliability, assessed by feeder types as:

- System Average Interruption Duration Index (SAIDI); and,
- System Average Interruption Frequency Index (SAIFI).

Both Safety Net and MSS performance information are publicly reported annually in the Distribution Annual Planning Reports (DAPR). MSS performance is monitored and reported within EQL daily.

1.6 Compliance obligations

Table 2 below outlines the relevant compliance obligations for this proposal.

Table 2: Compliance obligations related to this proposal

Legislation, Regulation, Code or Licence Condition	Obligations	Relevance to this investment
QLD Electrical Safety Act 2002	We have a duty of care, ensuring so far as is reasonably practicable, the health and safety of our staff and other parties as follows:	This proposal addresses PQ issues in Energex LV and MV networks which can cause

Legislation, Regulation, Code or Licence Condition	Obligations	Relevance to this investment
QLD Electrical Safety Regulation 2013	• Pursuant to the Electrical Safety Act 2002, as a person in control of a business or undertaking (PCBU), EQL has an obligation to ensure that its works are electrically safe and are operated in a way that is electrically safe.[1] This duty also extends to ensuring the electrical safety of all persons and property likely to be affected by the electrical work.[2]	safety risks to customers, staff, and plant equipment through planned network augmentation and remediation works, and extends the PQ monitoring ability of the network, which will allow Energex to respond proactively to issues before they cause safety risks.
Distribution Authority for Energex issued under section 195 of *Electricity Act 1994* (Queensland)	Under its Distribution Authority: • The distribution entity must plan and develop its supply network in accordance with good electricity industry practice, having regard to the value that end users of electricity place on the quality and reliability of electricity services. • The distribution entity will ensure, to the extent reasonably practicable, that it achieves its safety net targets as specified. • The distribution entity must use all reasonable endeavours to ensure that it does not exceed in a financial year the Minimum Service Standards (MSS)	This proposal introduces measures to improve Quality of Supply for customers, reducing the impact of PQ factors such as harmonics, disturbances or voltage fluctuations which can impact service quality.
National Electricity Rules (NER), Chapter 5	Schedule S5.1 of the National Electricity Rules, Chapter 5 provides a range of obligations on Network Services Providers relating to Network Performance Requirements. These include: • Section S5.1.9 Protection systems and fault clearance times • Section S5.1a.8 Fault Clearance Times • Section S5.1.2 Credible Contingency Events	This proposal introduces measures to control PQ issues covered by S5.1 including Magnitude of Power Frequency Voltage, Voltage Fluctuations, Voltage Harmonic Distortion, and Voltage Unbalance. By doing so this proposal improves Energex's ability to comply with the NER.
Queensland Electricity Act	Section 44A (1) of the Queensland Electricity Act states that it is a condition of a distribution authority that the distribution entity allow, as far as technically and economically practicable, a qualifying customer premise to connect one qualifying generator at the premises to its supply network.	This proposal will improve Energex's understanding of the impacts of DERs on the network and respond to voltage issues which currently limit the capacity of DERs which can be connected in LV networks, thereby allowing for optimisation of DER use and installation by Energex and addressing factors which will currently limit the ability of residential customers to connect DERs.

[1] Section 29, *Electrical Safety Act 2002*
[2] Section 30 *Electrical Safety Act 2002*

1.7 Limitation of existing assets

Energex has installed 22,000 Power Quality monitors over the current and previous regulatory control periods with successful quality of supply outcomes for both the network and customers. However, further works and extension of this monitoring program are required to ensure compliance and deliver additional benefits for Energex.

This section outlines:

- The benefits delivered from historical PQ Monitoring programs;
- The uptake of Solar PV in distribution networks; and,
- Additional limitations of the existing network which drive the need for extended PQ monitoring programs and traditional augmentation and remediation works.

1.7.1 Benefits of Historical Programs

Compliance with 230V AS61000.3.100 Standards

Energex PQ monitors are connected to the LV terminals of approximately 44% of the total population of distribution transformers across the network. The installed PQ monitors provide a real-time response on the state of the network in areas where no other measurements are available and are the primary source to report on compliance for 230V standard and all PQ parameters throughout the Energex network. Figure 1 shows the population of monitored distribution transformers, outlining those with voltages above the limits specified in AS61000.3.100 (V99%>253V) to June 2018.

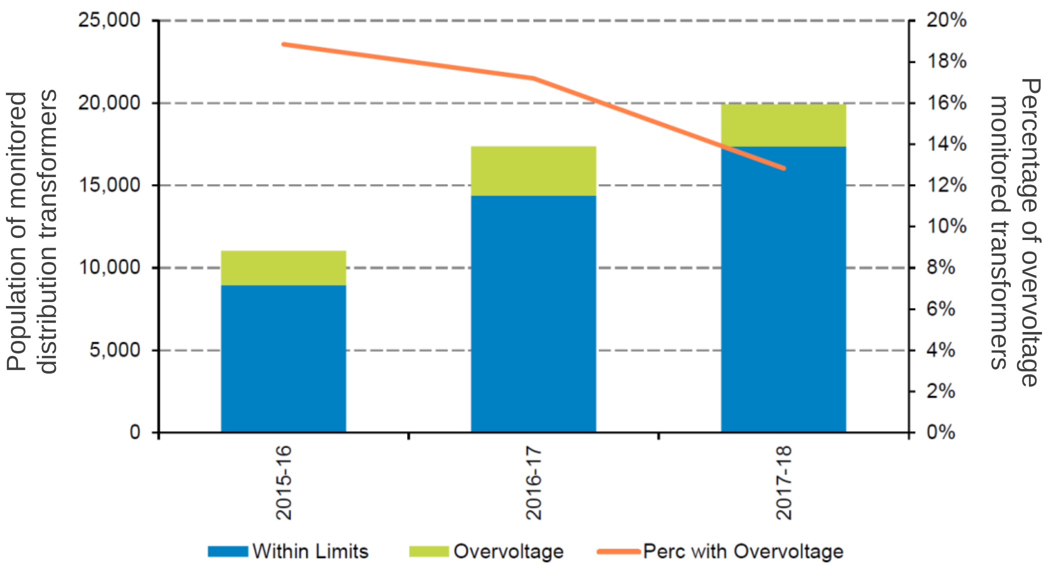

Figure 1: Population of monitored distribution transformers with over-voltage (V99%>253V)

Although Energex has largely achieved compliance in the transition to the 230V standard, there needs to be a greater number of transformers monitored to ensure the LV network is fully compliant with regards to voltage and all other PQ parameters. The risk of non-compliance is with the sites where there are no monitors and no information on transformer tap positions. Additional PQ monitors will provide greater coverage and limit assumptions and risk about non-monitored parts of the network.

Savings in Field Investigations

Remote availability of real time and periodic PQ data from the power quality monitors has saved travel time and site visit costs for the field crews. This includes the set up and recovery of ad-hoc monitoring equipment at the distribution transformer and/or customer premise, reduced need for specialised ad-hoc PQ monitoring equipment and software, and reduced risk for staff conducting the field investigation.

Figure 2 shows the reduction on number of voltage investigation jobs requiring site visits per month based on the last five years. PQ monitoring has resulted an approximately 30% reduction in overall investigation time and cost for voltage enquiries with field crews having remote access to PQ data before attending the sites (if site attendance is deemed necessary at all after remote analysis of data). Additionally, Quality of Supply investigation costs have been reduced as a result of historical monitoring data, remote access to PQ monitoring data, and wider visibility of the distribution network. However, temporary PQ monitoring is still often required to be installed at the connection point, hence the need for further monitors.

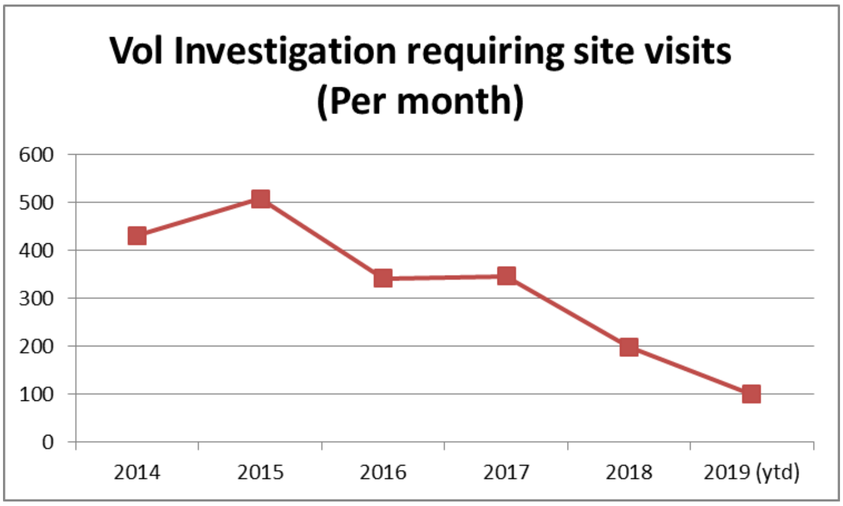

Figure 2: Reduction in voltage investigation jobs requiring site visits

Additional Benefits

Besides the estimated savings in operational cost of voltage investigation, benefits of PQ monitoring have included:

- Significant reductions in distribution transformer load checks on site.
- LV switching and load transfers are much quicker with minimal need to request load checks.
- Lesser generator use under contingencies as decisions can be based on historical load profiles.
- The Network Operation team can manage transfers with less capacity margin as they can observe loads in real time and make adjustments if necessary.
- Planning of LV ties and transfers are more accurate and faster with less reliance on simplistic load allocation models.
- Identification of any deviation of PQ parameters from acceptable performance levels through regular business reporting from the monitors. This includes prompt identification (and rectification) of sites with sustained high voltages with potential safety risk to the public/customers.

Due to multiple variables such as geographical locations of individual PQ monitors, customer numbers, distance from depot, crew availability, nature of Quality of Supply (QoS) enquiries, network topologies, and depth of required investigation it is very challenging to accurately model the operational cost benefits of individual PQ monitors. EQL will be exploring this aspect further as part of PQ mapping program.

1.7.2 Increasing Uptake of Small-Scale Solar PV

The following sections outline the trends observed in the Energex network regarding the uptake of Solar PV in LV networks. For more information, refer to the supplementary information provided in Appendix H.

Historical and Projected Growth of DERs

Energex has experienced rapid growth in Solar PV over the last five years, and now hosts the highest per-capita capacity of rooftop solar worldwide. Figure 3 shows the increase in connections since January 2012.

The growth rate has been approximately 34% per annum in the last five years. Over the 2017/18 financial year there were an average of 1,900 new systems with a combined capacity of around 12 MW connected per month. At the end of June 2018, there were 356,137 solar PV embedded generating systems connected to the Energex network with a total installed capacity of approximately 1,388 MW. During the 2018/19 financial year, distributed solar PV systems were connecting at an average rate of over 2,900 connections per month. At the end of June 2019, there were over 391,000 solar PV systems connected to the distribution network, with a total generation capacity of 1,664 MVA. At the LV level, Energex networks now have a solar penetration rate of approximately 40%.

Figure 3 also shows the projected growth of residential solar for Energex. It is very difficult to predict Solar PV uptake rates out as far as 2030 with any confidence given the range of influencing factors, including tariff incentives, capital cost, and customer behaviour in response to the rising price of electricity. The three scenarios modelled in Figure 3 assume that the cost of Solar PV systems has stabilised and the price of electricity from the grid is stabilised or reducing in real terms for customers. These two factors make it more likely that solar PV connections will decrease rather than increase. There is the possibility that further disruption through energy storage technologies such as standalone batteries or electric vehicle batteries integrated into existing solar PV systems could spur growth above the high scenario in the period to 2030, but at this stage, it is not considered likely.

The challenge for Energex is to incorporate the evolving behaviours and requirements of customers driven by the uptake of DERs into business as usual activities, allowing customers to take full advantage of intelligent grid technology benefits without impacting quality of service.

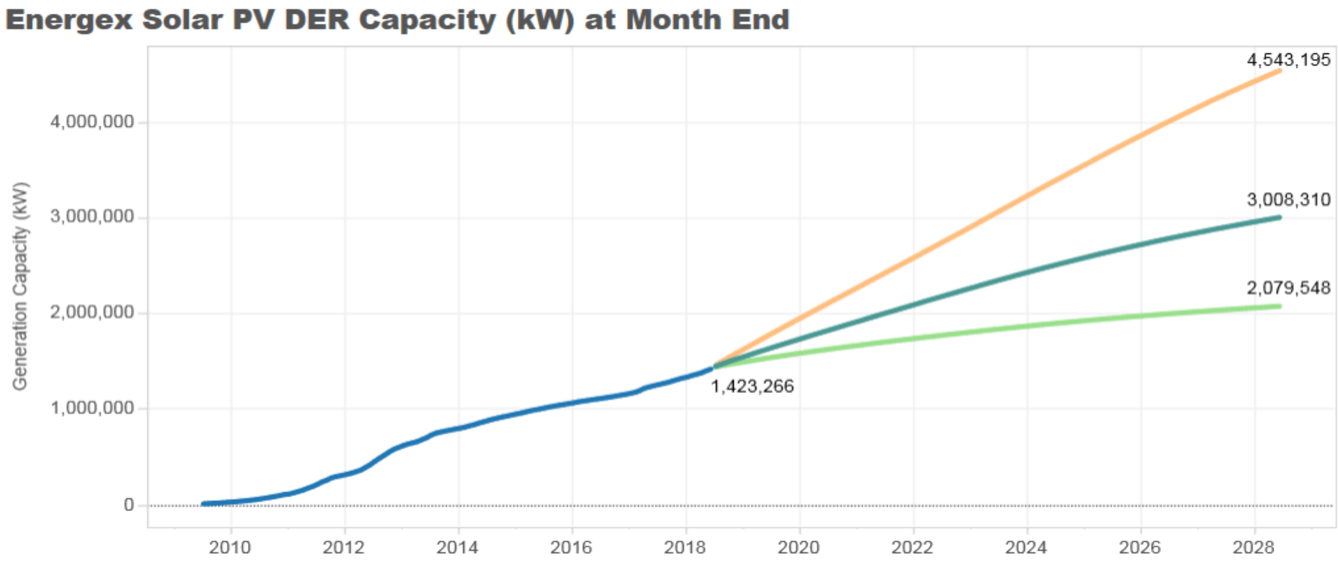

Figure 3: Real and Projected Solar PV Capacity Growth to 2028

Network Impact of DERs – Reverse Power Flow and Voltage Impact

Solar PV and other forms of embedded generation have a large impact on network power quality due to the emergence of bi-directional power flow into low voltage networks. Traditionally, distribution networks were designed to accommodate the flow of power in one direction from substations through to customers, from high voltage to low voltage systems. With the rise in distributed generation on the LV network, power flows can now occur in both directions leading to greater voltage regulation challenges to be managed and operational issues to be addressed.

The large number of connections of rooftop Solar PV in areas cause reverse power flows at times of peak solar generation. Figure 4 compares an example of a traditional and a high-solar penetration load profile on a distribution transformer, with reverse flow occurring during periods of peak generation. Approximately 60% of distribution transformers in the Energex network have Solar PV connected to them, and around 23% of the total population of the distribution transformers have PV penetration greater than 25% of their nameplate rating, which will result in reverse power flow back onto the HV during peak solar periods of the day.

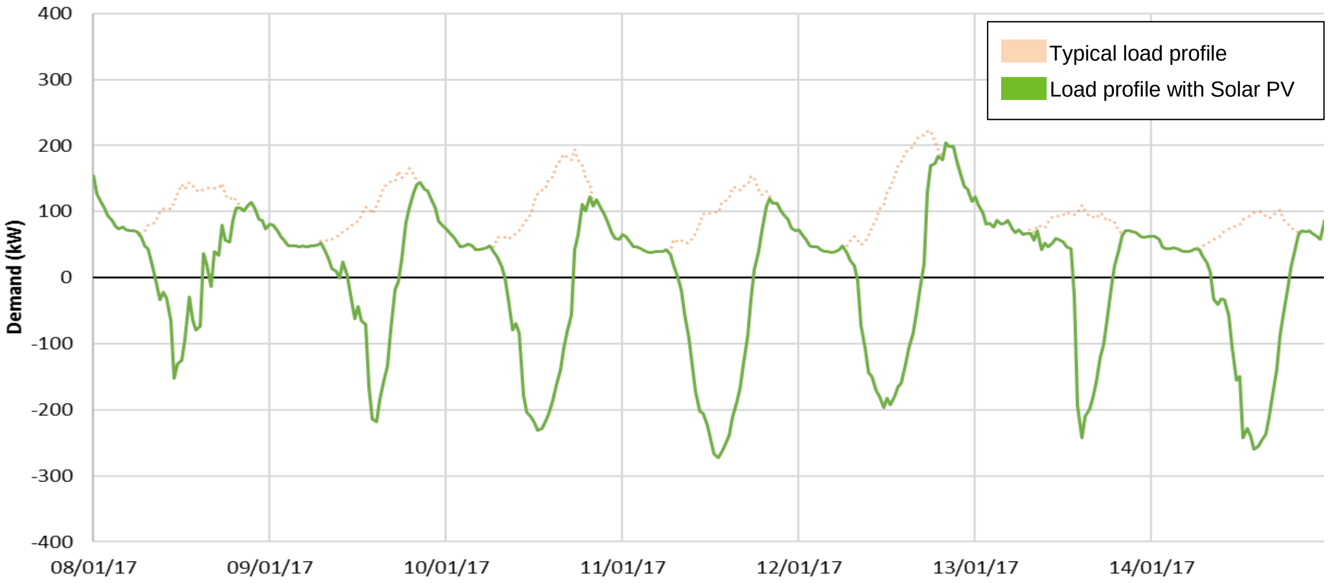

Figure 4: Example of traditional demand and solar load profile on a distribution transformer

Reverse power flow is less predictable and leads to both voltage rise and voltage drop along the feeding network, which must be managed to ensure voltage at customer terminals stays within statutory voltage limits. This additional voltage regulation required is very dependent on the actual network but is known to be worse in areas with overhead power line construction and longer LV circuit lengths connecting customers further away from supply substations. As solar PV penetrations continue to rise throughout Energex networks, reverse power flow and other associated PQ issues caused by solar PV will only become more prevalent.

Limited Visibility of DER Network Impact

The true difficulty in managing increased penetrations of DERs is the limited visibility of LV network power flows. While DNSPs will have visibility over most HV and MV networks through SCADA systems, there is limited direct monitoring of loads and voltages on LV networks, or data from direct monitoring of DER generation output or customer meters, as demonstrated by Figure 5.

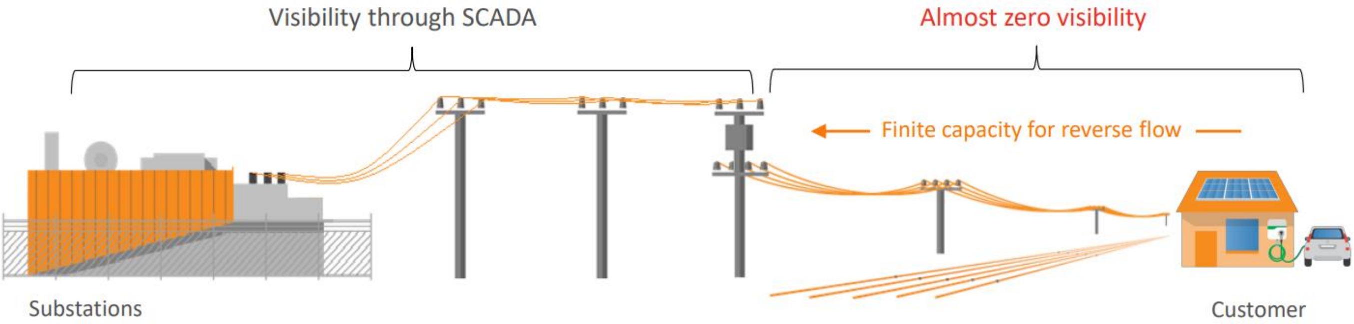

Figure 5: Limited LV Network Visibility for DNSPs (Source: AEMC, 2019)

Without increased monitoring of LV networks, issues such as reverse power flow are hard to identify in real-time and are often only noticed through customer complaints and enquiries. It is difficult to determine where constraints exist, and where they will develop in the future, limiting the ability of DNSPs to plan for increased DER integration. The AEMC recently highlighted the need for increased LV network monitoring capability in a review paper titled "Integrating DERs for the Grid of the Future", published in June 2019. The paper acknowledges the current constraints which DNSPs such as Energex experience, and outlines the need for additional monitoring and data collection in LV networks in order to support optimal use of DERs and network planning.

Business Impact – Increasing QoS Enquiries

Although the network has achieved compliance with the new 230V standard, issues with other network PQ parameters continue to lead to Energex receiving Quality of Supply (QoS) complaints from customers. Since 2013 the percentage of QoS enquiries (complaints) across the Energex networks for Solar PV related issues have ranged from 40 to 55% of all QoS enquires. Figure 6 shows the actual and projected number of QoS complaints due to Solar PV issues. Transition to the 230V standard contributed to a reduction in network voltages, reflected in a reduction in solar PV related enquiries in 2018 compared to 2017. However, the forecast increases in PV penetration are expected to cause a proportional rise in PV related QoS complaints.

Increasing PQ monitoring capability in the network will improve Energex's understanding of the causes and effects of different PQ issues, and allow for real-time detection or indication of PQ issues, thereby improving customer QoS.

Increased visibility of the network will also assist Energex with addressing issues caused by network equipment failure (such as voltage regulator failure or tap change issues) which can occur at any time resulting in voltages outside standard and will require real time detection and subsequent remediation. Greater real-time monitoring capacity will allow Energex to understand and proactively respond to network issues before they have customer or compliance impacts.

EQL's Customer Quality of Supply strategy for 2020-25 has a focus on monitoring distribution transformers that indicate a high percentage of customers with embedded generation. Increasing Energex's understanding of the impact of DERs on LV and MV networks will have the following benefits:

- **Allowing increased uptake of DERs:** Additional PQ monitors on transformers with a high penetration of solar PV will provide a true indication of how the embedded generation is being used within (or impacting) the LV network, and if reverse flow is occurring into the MV network. If it can be demonstrated that embedded generation is used within the LV network (i.e. no reverse flow onto the MV), it will be possible to increase the percentage of embedded generation onto the transformers without causing reverse flow, or to reduce the amount of customer curtailment which is currently necessary to ensure compliance.

- **Improving safety outcomes:** Increased monitoring will help to ensure that loads and generation currents within LV networks are balanced to ensure minimal neutral currents, improving safety outcomes. Existing PQ monitor data has been used to calculate neutral current parameters, and with further development around this calculation it is anticipated that further safety assumptions can be made.
- **Efficient investment for remediation or augmentation works:** More data on PQ parameters will help Energex to make more informed and efficient investment decisions about network augmentation or voltage remediation works, delivering improved customer outcomes in a cost-effective manner.
- **Reducing instance and cost of QoS enquiries:** With improved PQ monitoring capability, Energex can reduce the costs associated with QoS enquiries, and proactively plan network augmentation or voltage remediation works where necessary to reduce QoS issues for customers.

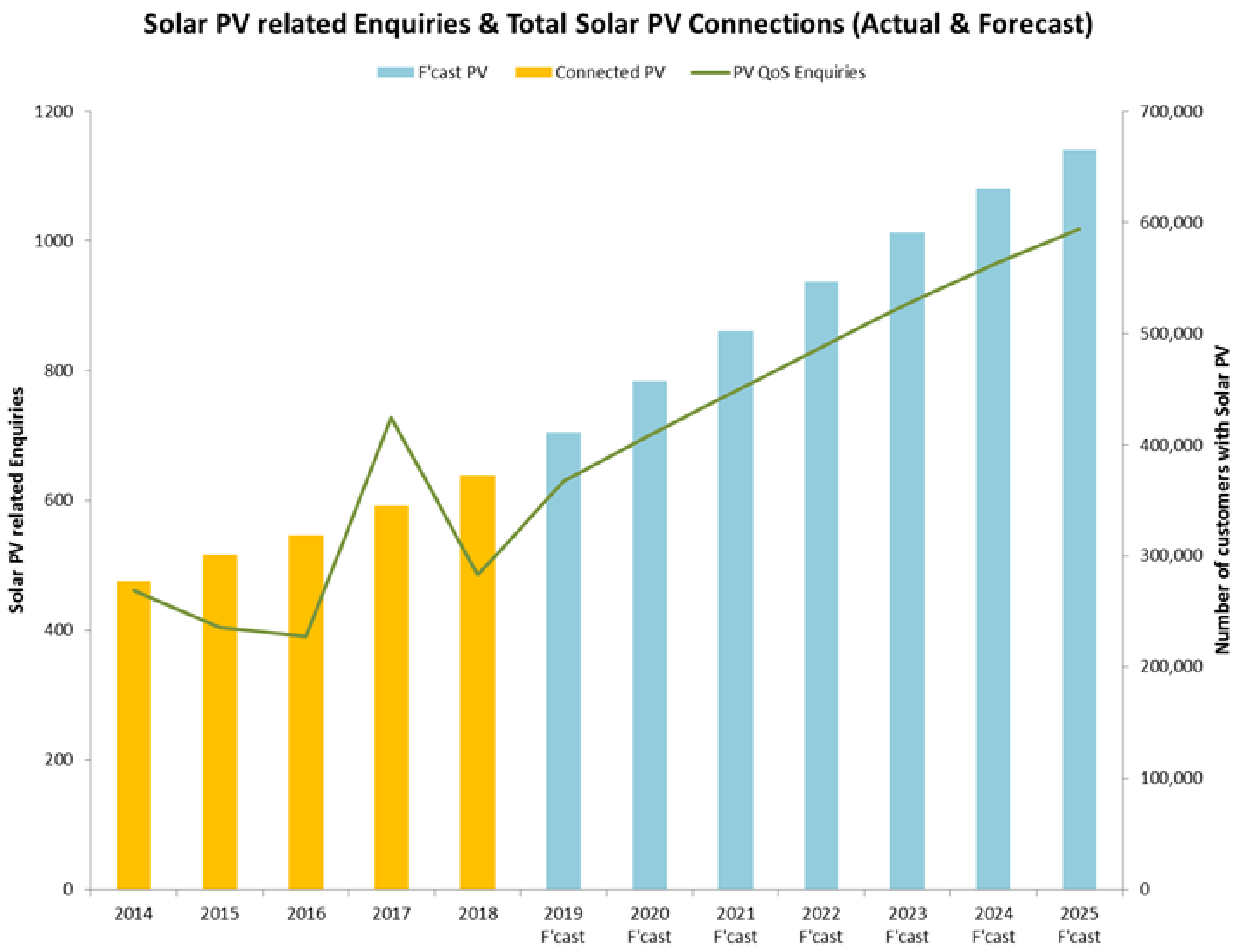

Figure 6: Number of Solar PV QoS enquiries and total Solar PV connection (Actual and Forecast)

1.7.3 Additional Limitations of the Existing Network and Programs

Improving Understanding of Network PQ Health, and Reducing Modelling Costs

In the absence of suitably placed PQ monitors with communications capability, and subsequent lack of network performance history, Energex is reliant on confirmation of network health issues from multiple other sources. Field work for short-term monitoring and data collection is often necessary, using temporary PQ monitors, voltage regulators, or revenue meter data in the place of PQ monitor datasets. This method of validation results in significant work required from multiple groups at Energex, and significant additional labour and equipment costs.

In addition, the benefit of short-term monitoring is limited because of the small window of data capture. For temporary recorders the data collection period is typically not more than two weeks, and for revenue metering, up to three months. Both datasets are also subject to the time of year and the data collected will not always capture the period of interest. Additionally, use of revenue meter data will not always be useful as the quality of the data depends on the age and types of meters.

With the extension of PQ monitoring capability throughout the Energex network, the necessity of manual data extractions such as these would be reduced, with PQ monitors capturing real-time data during all periods of the year, improving data and model quality and reducing labour costs.

Improving Customer Experience through a Proactive Response Model

Energex's traditional response model is reactive, responding to issues following customer complaints, appliance damage, identified issues from network modelling, and post-event recording. With Energex's existing PQ monitoring capability, there have been numerous occasions where PQ monitors have identified low voltage wires down, blown fuses, unbalance and outages before the customers have made reports.

Expansion of the current PQ monitoring capability will allow Energex to move further from a reactive to proactive response model. It will also address existing and emerging network issues that adversely affect safety and Quality of Supply before potential equipment damage occurs, safety is impacted, and customers become aware of the issue. Improved data sets when performing Quality of Supply investigations will allow for better identification of the source of disturbances and the impact on customer supply. Through a proactive response model, a reduction in quality of supply related customer complaints and enquiries is expected, along with a reduction in customer claims for equipment damage.

Business Requirements – Transitioning to an Intelligent Grid

Energy Queensland's proposed PQ monitoring program also supports the transition to an intelligent grid, as proposed under our Future Grid Roadmap and Intelligent Grid Technology Plan. Visibility of all levels of the network is fundamental to the industry's transition from its current capacities to those of any future optimised DER world, and is required particularly to co-ordinate & optimise two-way energy flows on the network which arise from increased connection of DER.

As part of this transition, Energy Queensland is proposing to implement systems such as an Advanced Distribution Management System (ADMS), a Distributed Energy Resources Management System (DERMS) and a Low Voltage Network Management Platform. These systems will allow coordination of customer DERs, which will increase utilisation of existing assets, reduce network augmentation, and enable better outcomes for customers in affordability and choice. However, the increased visibility from the proposed PQ monitoring program is a key requirement for the effective implementation of these systems.

Beyond 2020, together with other initiatives, the PQ monitoring program will enable application of intelligent grid solutions (including planning and management of micro-grids), development of technology platforms for monitoring and analysing of distributed energy resources and support future PQ initiatives on South East QLD LV networks.

Business Requirements – Service Target Performance Incentive Scheme

The AER's Service Target Performance Incentive Scheme (STPIS) includes a performance index to report on the momentary supply interruption events (MAIFIe). MAIFIe measures the average frequency of momentary interruption events experienced by customers during a reporting period. A sustained interruption event is where one or more unsuccessful attempts to restore supply occur, and any associated momentary interruptions events are not included in the calculation of MAIFIe. The AER currently accepts that Energex does not have the capability to practically monitor and report MAIFIe but understands that the business is committed to establishing this capability in future. Delivery of the scope of work in this proposal will assist to achieve MAIFIe monitoring capability across the Energex High and Medium Voltage distribution networks and meet AER's potential future requirements for MAIFIe reporting.

2 Counterfactual Analysis

2.1 Purpose of asset

Energex has installed approximately 22,000 Power Quality monitors over the current and previous regulatory control periods with a successful quality of supply outcomes for both the network and the customers. Energex PQ monitors are connected to the low voltage (LV) terminals of the distribution transformer and provide a reflection of the medium voltage network including the PQ parameters. The installed PQ monitors have provided a real-time response on the state of the network in areas where no other measurements are available, and PQ Monitors are the primary source to report on compliance for 230V standard throughout the Energex network.

2.2 Business-as-usual service costs

In the regulatory control period 2015-20, Energex submitted a proposal for $38.4M for power quality monitoring and PV augmentation work. The scope of recommended works included installation of PQ monitors, rectifying PV related power quality issues for network and customers and also on the upgrading of obsolete models of modems on PQ devices to obtain a better understanding of the PQ parameters in selected parts of Energex network. The program is currently being rolled out with more than 4,000 PQ monitors installed as of June 2018.

These investments provided multiple benefits to customers including:

- Savings in time to identify customer enquiries on possible QoS issues.
- Savings in time and payment costs for claims by customers for failed appliances and equipment.
- Savings in time and the associated costs to install temporary recording equipment for network analysis to determine PQ parameters and compliance.
- Savings in time and costs associated with identifying possible need for network augmentation.
- Ability to ensure 230V compliance as part of regulatory requirements.

Energex's expenditures on PQ monitoring program, customer voltage remediation works and PV augmentation works for 2015-20 regulatory year are shown in Table 3, Table 4 and Table 5 respectively. PQ monitoring expense shown in Table 3 also includes the PQ device modem upgrades. As shown in Table 4, the customer voltage remediation expenditures have slightly increased due to growth in voltage complaints and identification of non-compliance parts of network.

Table 3: Energex PQ Monitoring program expense 2015-20

	2015/16	2016/17	2017/18	2018/19 Budget	2019/20 Forecast	Total 2015-20
Expenditure ($M direct, 2020)	$1.21	$2.82	$7.63	$3.46	$1.57	$16.69

Table 4: Energex Customer voltage remediation expense 2015-20

	2015/16	2016/17	2017/18	2018/19 Budget	2019/20 Forecast	Total 2015-20
Expenditure ($M direct, 2020)	$0.64	$0.76	$1.31	$3.64	$3.64	$9.99

Table 5: Energex PV Augmentation program expense 2015-20

	2015/16	2016/17	2017/18	2018/19 Budget	2019/20 Forecast	Total 2015-20
Expenditure ($M direct, 2020)	$0.26	$3.79	$4.23	$2.75	$2.75	$13.78

2.3 Key assumptions

The counterfactual analysis in this case is a ‘Do Nothing’ scenario, where no action is taken and there would be no additional expenditure for the monitoring program, or additional remediation or augmentation works.

While the PQ programs of the current regulatory period have provided significant benefits to the network with regards to compliance, safety, customer experience, and investment savings, further customer voltage remediation, solar PV augmentation, and PQ monitoring works are required.

Under a Do-Nothing scenario, with the forecast increase in penetrations of Solar PV and other DERs such as household batteries and electric vehicles, and in light of historical volumes of expenditure required to respond to respond to PQ issues, it is highly likely that the network will likely see increased voltage rise and imbalance issues resulting in more customer complaints and unresolved PQ issues. Energex will be forced to respond reactively to these issues, having the following impacts on its operation:

- **Increased operating cost due to reactive emergency works:** Without planned voltage remediation or solar PV augmentation programs to address known PQ issues, Energex will be forced to respond reactively to issues as they arise and are reported by customers, incurring additional cost due to the ad-hoc nature of works.
- **Higher safety risk associated with reactive works:** The risk to network staff and customers is higher under a reactive PQ response program, as PQ issues can expose persons to unregulated voltages, and cause damage to network or customer equipment.
- **Risk of non-compliance:** Without a planned program of works, Energex will be forced to respond reactively to issues, increasing the risk that non-compliant voltages will occur.

The counterfactual scenario also introduces the following issues for customers:

- **Increased risk of curtailment:** Without sufficient monitoring capability of LV networks, it is often difficult to diagnose the cause of PQ issues, and Energex can be forced to curtail customer DER exports in order to ensure compliance with voltage standards. Without a planned program of PQ monitoring or Solar PV augmentation, the likelihood of customer curtailment will increase.
- **Damage to customer equipment:** PQ issues in LV networks can cause damage to customer equipment, particularly sensitive electronic devices which have safety thresholds for voltage parameters. The counterfactual scenario will likely increase the risk of damage to customer equipment and increase Energex’s exposure to customer damage claims.

Given the high likelihood of PQ issues arising during the next regulatory period that will need to be addressed through capital programs, the counterfactual program presents a poor asset management approach to network operation, and introduces unacceptable risks to customers, staff, and plant.

Additionally, limited availability of PQ data from LV networks, and lack of PQ data from MV networks, will impact Energex’s ability to plan for augmentation of existing network and connection of new customers. In order to drive cost-effective investment and support Energex’s transition to an intelligent grid in line with internal strategies, customer engagement, and government policies, Energex must introduce infrastructure that improves visibility of all levels of the network.

2.4 Risk assessment

This risk assessment is in accordance with the EQL Network Risk Framework and the Risk Tolerability table from the framework is shown in Appendix E.

Table 6: Counterfactual risk assessment

Risk Scenario	Risk Type	Consequence (C)	Likelihood (L)	Risk Score	Risk Year
Multiple customers' supply voltage is outside the regulated range (+10/- 6% of 230 V). These unregulated voltages lead to significant damage to customer equipment resulting in significant impact on any restoration or planned works equating to business cost >$500,000.	Business	4 *(Significant impact on any restoration or planned works equating to business cost >$500,000)*	3 *(Unlikely)*	**12** ***(Low Risk)***	2020
Inability to monitor and manage voltage in the regulated range (+10/- 6% of 230 V) and Audio Frequency Load Control (AFLC) signal levels, particularly in areas with high Solar PV penetration and long low voltage circuit lengths, potentially leads to breaching regulated standards and an improvement notice being issued by the regulator.	Legislative	4 *(Improvement notice issued by regulator)*	3 *(Unlikely)*	**12** ***(Moderate Risk)***	2020
Inability to monitor and manage supply voltage outside of the regulated range (+10/- 6% of 230 V) and AFLC signal levels, particularly in areas with high Solar PV penetration and long low voltage circuit lengths, potentially results in an increase to customer light flicker and/or appliance/network equipment damage. This results in disruption to businesses and essential services.	Customer	3 *(Disruption to a large business or essential service)*	4 *(Likely)*	**12** ***(Moderate Risk)***	2020
Inability to monitor and manage voltage and AFLC signal levels, particularly in areas with high Solar PV penetration, potentially leads to poor network planning and business investment decisions. Energex is unable to deliver strategic initiatives related to optimal asset design with respect to new technologies without incurring costs resulting in significant cost premium (>50% of estimates) to deliver agreed strategic initiatives.	Business	3 *(Significant cost premium (>50% of estimates) to deliver agreed strategic initiatives)*	4 *(Likely)*	**12** ***(Moderate Risk)***	2020
Customer supply voltage is outside the regulated range (+10/- 6% of 230 V). Inadvertent contact with customer appliance or network equipment with very high voltages results in a single fatality.	Safety	5 *(Single Fatality)*	2 *(Very Unlikely)*	**10** ***(Low Risk)***	2020

Risk Scenario	Risk Type	Consequence (C)	Likelihood (L)	Risk Score	Risk Year
Inability to monitor and manage supply voltage outside of the regulated range (+10/- 6% of 230 V) and AFLC signal levels, in areas with high Solar PV penetration and long low voltage circuit lengths results in abnormal network configuration while reactive work is undertaken to rectify issues	Business	3 *(Abnormal network configuration)*	2 *(Very Unlikely)*	**6** ***(Low Risk)***	2020

Further details of the risk ratings and descriptions can be found in Energy Queensland's Network Risk Framework.

2.5 Retirement or de-rating decision

Ensuring that supply Power Quality meets the required standards for voltage and frequency is crucial for the correct function of the Energex network and compliance with AER and NER standards and regulations. Without PQ monitoring devices, Energex would be unable to adequately monitor or predict PQ issues, resulting in poor customer quality of supply outcomes and inefficient investment into network augmentation or remediation works to address these problems. Existing network devices such as Automatic Circuit Reclosers (ACR's) and System Control and Ancillary Data Acquisition (SCADA) have no or very limited ability to provide remote visibility of PQ parameters. As such, retirement of PQ monitoring devices cannot be considered.

3 Options Analysis

Due to the complexity of the Energex network and the large number of sites involved, the management of power quality presents many challenges. To address these challenges a systematic approach is being adopted. This involves:

- Establishing objective measures and supporting systems for prioritising remedial works;
- Developing network models down to the LV network that allow problem areas to be predicted;
- Establishing suitable data acquisition and reporting systems to identify problem areas and implement remediation works;
- Tracking improvements from remediation programs; and,
- Measuring results to refine the network model and remediation options.

Options for programs of work to adopt the systematic approach outlined above have been developed for consideration in this business case.

3.1 Options Considered but Rejected

The following two options were considered but rejected when developing a program of works specific to PQ Monitoring:

- **Automatic Circuit Reclosers (ACRs) with SCADA for PQ Monitoring:** Use of ACRs was considered at a high level as a method for remote monitoring of Power Quality but rejected as these line devices have very limited ability to measure PQ parameters.
- **Customer Meter Data for PQ Monitoring:** As part of alternate strategic thinking on PQ issues for the customer and the network, EQL is currently involved in a research project as part of the of Australian Renewable Energy Agency (ARENA) funded Solar Enablement Initiatives Low Voltage State Estimation Algorithm (SEA) program, using smart meters and LV monitors to produce a real-time network model. Implementation of SEA at Energex has included a prototype application and field trial for managing the operational state of the network. Results to date demonstrate there are significant improvements in accuracy when a reasonable population of nodes are monitored. SEA is not directly part of our proposal for the 2020-25 regulatory period as it is still in the research collaboration phase.

3.2 Identified Options

3.2.1 Network Options

The identified options for this program of works are as follows:

- Option 1 – Do Nothing;
- Option 2 – PV Augmentation and Voltage Remediation works only; and,
- Option 3 (Recommended) – Extend PQ monitoring capability and perform augmentation and remediation works (Full Program).

Option 1 – Do Nothing

The complete 'Do Nothing' counterfactual option was considered in this analysis as the option where no Capital works programs relating to PQ monitoring are planned ahead of time. However, given the necessity of these programs for compliance, safety, and customer quality of supply, it is likely that Capital costs will still be incurred during the next regulatory period for this option, albeit in the form of an unplanned, reactive response.

Option 2 – PV Augmentation and Voltage Remediation works only

This option anticipates the need to perform customer voltage remediation and solar PV augmentation works during the next regulatory period in order for the network to remain compliant with relevant safety and performance standards. No extension of PQ monitoring capability is considered in this option.

Scope of works for customer voltage remediation

The ability to manage the growing complaints from customers experiencing audible noise interference in their appliances and LED (light emitting diode) light flicker is driven by Customer Quality Supply Strategy. This issue is associated with increasing penetration of solar PV on the network. Energex endeavours to keep the Audio Frequency Load Control (AFLC) 1050 Hz signal voltage under 10 V, which meets the requirements of the (AS61000.2.12) so that appliances have immunity (no loss of function or degradation of performance) to the AFLC signals.

Table 7 outlines the programs of work developed to address this need.

Table 7: Scope of works for customer voltage remediation

Options	Program number	Program description
Residential AFLC Filter	CA33	Program of Works CA33 will allow targeted remediation works in areas with known abnormally high AFLC signals exceeding 10V where other methods of mitigation (as per Energex work practice WP1352) have proven to be ineffective. Installation of three-phase passive L-C (sinking) filters at selected existing LV pillars (or additional pillars) and poles in residential estates to mitigate abnormal AFLC signal. The program will target areas with known AFLC signal issues associated with high solar PV penetration and low transformer utilisation. Sites will be prioritised in coordination with other power quality programs to maximise the net benefit.
Customer Voltage Investigation Remediation Work	CA50	This program is focused on quality of supply queries from the customers which include high/low voltage, voltage dips, voltage sag/swell and flickering lights. It typically includes distribution transformer replacement and LV system augmentation. The program targets areas where complaints are relatively high, approximately above 25%.

Scope of works for Solar PV augmentation

The Solar PV related program of works for 2025-25 will target potentially high impact and moderate impact areas identified as priority sites over the next five years based on forecast growth. The programs will be coordinated to avoid unnecessary overlap of other PQ programs. In some cases, a combination of Augex (Augmentation Expenditure)/OPEX (Operating Expenditure) programs will be required for particular areas. Only a small proportion of the overall potential sites will be targeted in the next five years, with the assumption that the worst will be addressed while gaining greater knowledge about the impacts and taking into account future requirements that will help to mitigate impacts.

The Solar PV related augmentation program is developed based on the following:

- Analysis of power quality of networks with existing PV hosting capacity constraints.
- Forecasted number and capacity of PV systems.
- Studies of networks affected by high penetration of Solar PV systems.
- Historic solar PV systems' growth and capital investments.

- Requirements to maintain new statutory voltages range of 230V +10/-6%.
- Connection Standard for Micro Embedded Generation units.

The costs of addressing the Solar PV network impacts are based on the regulatory requirement to maintain new statutory voltages range of 230V +10/-6% and will mainly address worst areas emerging from the growth of Solar PV on the network. By delivering the Solar PV Augmentation program, Energex will be able to minimise the PV related PQ complaints which are currently 43% of total complaints. This program will also further enhance PV hosting capacities of the LV network.

New technologies are now becoming commercially available for managing voltage on the supply and customer side of the meter. On the network side, this mainly includes electronic devices that can automatically regulate the voltage on the LV supply. On the customer side, this includes Australian Standard AS4777 compliant Solar PV inverters with reactive control capability and power export limiting devices.

Table 8 outlines the programs of work developed to address this need.

Table 8: Scope of works for solar PV augmentation

Options	Program number	Program description
Solar PV Augmentation	CA46	Network initiated augmentation works relating to the remediation of issues caused by Solar PV installations with targeted remediation works in areas with existing PV hosting capacity constraints. This work is typically focused on distribution transformer replacements and low voltage (LV) system augmentation. The program will target pole-mounted distribution transformers with Solar PV penetration exceeding 25% of nameplate rating and transformers with long and high resistivity LV circuits exceeding 400 metres. Criteria of targeting distribution transformers with greater than 25% penetration of solar PV systems of nameplate rating is based on a balanced engineering assessment between a variety of transformer sizes and types, connected customer categories, loading and voltage profiles and areas of supply. In the same time, selection of LV circuits with the length of backbone conductor greater than 400 meters is based on technical and physical characteristics of LV networks, voltage performances, load and customer densities, customer categories and the distance of solar PV systems from the distribution transformer. Selection of sites is coordinated with other power quality programs to maximise the net benefit.
LV Switched Capacitors – Overhead Network	CA31	Installation of pole mounted three phase capacitors with individual phase voltage control to remediate voltage management issues caused by Solar PV installations. The program will target pole-mounted distribution transformers with solar PV penetration exceeding 25% and transformers with long LV circuits exceeding 400 metres and average voltage unbalance exceeding 30% (as known, maximum allowable voltage unbalance is 5%). By delivering this new initiative of LV switched capacitors, LV augmentation programs can be further reduced beyond 2025
LV Electronic Voltage Regulator – Underground Network	CA32	Installation of a pad mounted three phase LV regulator with individual phase voltage control to remediate voltage management issues caused by Solar PV installations. The program will target pad mounted distribution transformers with solar PV penetration exceeding 60% and transformers with long LV circuits exceeding 800 metres and average voltage unbalance exceeding 30%. A small number of LV electronic voltage regulator units were trialled between 2014 and 2016. The trial demonstrated the effectiveness of controlling the voltage to customers in the vicinity and downstream of the installation with diminishing benefits for upstream customers.

Options	Program number	Program description
Voltage Management OLTC Distribution Transformer	CA30	Replacement of a standard pole mounted distribution transformer with off-loads tap changer with an equivalent rated transformer with integral On-Load Tap Changer (OLTC). This will allow automatic control of voltages at the distribution transformer LV terminals. The program will target pole-mounted distribution transformers with Solar PV penetration exceeding 25% of the nameplate rating and transformers with long LV circuits exceeding 400 metres experiencing voltage management issues. Voltage management through OLTC is part of an emerging suite of technologies and advanced controls that will enable greater levels of Solar PV penetration to be connected to the LV network. By delivering this new initiative of OLTC transformers, it is expected that LV augmentation programs can be reduced beyond 2025.

The total CAPEX spend on CA46 for 2015/16 to 2018/19 has been $11.02M with estimated $2.73M for the remaining of this regulatory period. Hence the proposal sees a 25% reduction in the CAPEX associated with PV remediation works (in terms of 2019/20 direct cost)

CA30, CA31, and CA32 are new initiatives with a total CAPEX proposal of $2.12M. Since PV related QoS are the predominant cause of customer complaints and increasing PV penetrations will cause broader network issues, it is prudent to target sites with higher PV penetrations and longer high-resistive LV feeders with these programs. In addition, the investment will be optimised by the analytics supported by data from PQ monitors where available.

Option 3 (Recommended) – Extend PQ monitoring capability and perform augmentation and remediation works (Full Program)

Option 3 represents the full program of work developed for this Power Quality Program. All augmentation and remediation work programs presented in Table 7 and Table 8 are included in this option. Option 3 also includes the extension and upgrade of the existing PQ Monitoring capability in the Energex network, by connecting PQ monitors to a further 8% of distribution feeders.

Table 9 outlines the programs of work developed to extend the PQ monitoring capability. Refer to Appendix I for more information about the design of the PQ monitoring program.

Table 9: Scope of works for power quality monitoring

Options	Program number	Program description
Distribution Transformer Monitors – Pole Mounted (CA15) and Pad-Mounted (CA44)	CA15 and CA44	Replacement of the existing pole or pad mounted distribution transformers' manually read Maximum Demand Indicators (MDI) with power quality monitors at designated sites. The program will target pole-mounted distribution transformers with solar PV penetration exceeding 25% and transformers at the end of 11kV feeders. This is a continuation of an existing program to establish remotely read power quality monitoring on three-phase pole or pad mounted distribution transformers. The numbers of sites are proposed for PQ monitoring program during 2020-25 are based on the annual PV penetration growth rate and new distribution transformer growth rate of approximately 1%.
MV Smart Metering Sensors – Pole Mounted	CA29	Installation of MV smart metering sensors on distribution feeders to provide PQ data and increase observability of the MV network remote from the zone substation. This is a new PQ program that supports real-time PQ analysis, performance reporting systems, voltage management and remediation programs.

Options	Program number	Program description
		Works CA29 program involves the installation of PQ monitoring sensors to measure the three-phase voltage and currents along an 11kV feeder. The estimated number of sites for MV smart sensors installation is based on the total number of distribution feeders exceeding Solar PV penetration by 25%.
Low Voltage Circuit Monitors – Pole Mounted	CA48	Installation of remotely read three phase PQ monitors on selected pole sites on the overhead LV network to identify potential voltage compliance issues and provide input into network compliance modelling. This program will target pole-mounted distribution transformers with solar PV penetration exceeding 25% and high resistive LV feeder with backbone length greater than 400m. This length has been selected based on the analysis of LV network configurations with different PV penetration levels and associated load and voltage profile.
Network Device Modem Upgrades	CA55	Modem upgrades (transition of old 2G/3G to the new generation of 4G modems) on the existing power quality monitors. The modem upgrade is expected to be completed by early 2021/22.

3.2.2 Non-Network Options

With the uptake of smart-meters and internet of things (IoT) solutions throughout the Energex network at customer residences, options for monitoring grid performance and use patterns by utilising existing smart assets are emerging.

EQL is currently involved in a research project as part of the of Australian Renewable Energy Agency (ARENA) funded Solar Enablement Initiatives Low Voltage State Estimation Algorithm (SEA) program, using smart meters and LV monitors to produce a real-time network model. Results to date demonstrate there are significant improvements in accuracy when a reasonable population of nodes are monitored. Extended transformer monitoring in South East Queensland provides significant benefits to the accuracy of MV state estimation compared with smart meters. A significant population of smart meters or LV monitors are required to provide accurate LV state estimation.

The use of smart-meter data to model LV networks aligns with a recommendation presented by the AEMC in their recent paper “Integrating Distributed Energy Resources for the Grid of the Future”, for DNSPs, in collaboration with industry and consumer representatives, to identify additional meter data that should be collected and made available in order to support LV network visibility. Discussions with metering service providers are ongoing to agree on a reasonable price to procure suitable network data from their growing Smart Meter population which can be integrated into Energy Queensland data platforms and will also contribute to the SEA performance. SEA is not directly part of our proposal for the 2020-25 regulatory period as it is still in the research collaboration phase.

3.3 Economic Analysis of Identified Options

3.3.1 Cost versus benefit assessment of each option

The Net Present Value (NPV) of each option has been determined by considering costs and benefits over the program lifetime from FY2020/21 to FY2039/40, using the EQL standard NPV analysis tool. The following costs and benefits have been considered for each option.

Capital Costs (CAPEX)

For each of the options assessed, a capital cost has been developed based on the planned and unplanned works which would likely be incurred during the next regulatory period. Table 10 outlines the key assumptions which were used to develop the CAPEX for each option.

Table 10: Options Capital Cost Assumptions Summary

	Capital Cost Category		
Option	**Voltage Remediation**	**Solar PV Augmentation**	**PQ Monitoring**
Option 1 – Do Nothing	The full scope of works outlined in Table 7 is considered necessary for compliance, and therefore will be carried out in an unplanned manner with an emergency premium of 30% in the Do-Nothing case.	The full scope of works outlined in Table 8 is considered necessary to respond to customer complaints during the next regulatory period, but it is assumed that these works can be carried out in a more planned manner without emergency costs.	N/A
Option 2 – PV Augmentation & Remediation Only	Full scope of works as outlined in Table 7	Full scope of works as outlined in Table 8	N/A
Option 3 – Full Program (Recommended)	Full scope of works as outlined in Table 7	Full scope of works as outlined in Table 8	Full scope of works as outlined in Table 9.

For the specific programs outlined in Table 7, Table 8, and Table 9, capital costs were developed based on the unit rates outlined in Table 11. All unit rates are based on high-level estimates and are in line with typical expenditure in historical PQ programs. Unit rates also take into account both typical labour and materials costs, and the potential for geographical bundling of works.

Table 11: Unit Rate Assumptions for All Programs

Program Number	Description of CAPEX	Unit Rate ($/unit)
	Power Quality Monitoring	
CA15	Installation of LV Distribution Transformer Overhead PQ Monitors:	$2,987
CA44	Installation of LV Distribution Transformer Pad-Mount PQ Monitors:	$5,083
CA48	Installation of end-of line LV Distribution Transformer Overhead PQ Monitors	$2,283
CA29	Installation of Medium Voltage (MV) PQ Monitors	$6,877
CA55	Performance of Modem Upgrades on Existing PQ Monitors	$393
	Customer Voltage Remediation	
CA33	Retrofit LV AFLC Filter	$6,351
CA50	CAPEX Customer Voltage Remediation Work	$20,178
	Solar PV Augmentation	
CA46	Solar PV CAPEX Remediation Work	$66,386
CA30	Voltage Management – OLTC Pole Transformer	$24,273
CA31	Voltage Management – Overhead LV Switched Capacitors	$8,697
CA32	Voltage Management – Underground LV Electronic Regulator	$60,086

Installation Program

For the specific programs outlined in Table 7, Table 8, and Table 9, programs of work were developed, and have been outlined in Table 12.

Table 12: Installation Program – All Programs

Program	Units Replaced / Installed					
	FY 20/21	FY 21/22	FY 22/23	FY 23/24	FY 24/25	Total
	PQ Monitoring					
CA15	250	250	250	250	250	**1,250**
CA44	250	250	250	250	250	**1,250**
CA48	250	250	250	250	250	**1,250**
CA29	0	120	120	120	120	**480**
CA55	3,596	0	0	0	0	**3,596**
Total New PQ Monitors	**750**	**870**	**870**	**870**	**870**	**4,230**
Total PQ Monitoring Works	**4,346**	**870**	**870**	**870**	**870**	**7,826**
	Customer Voltage Remediation					
CA33	100	100	100	100	100	**500**
CA50	100	100	100	100	100	**500**
Total	**200**	**200**	**200**	**200**	**200**	**1000**
	Solar PV Augmentation					
CA46	30	30	30	30	30	**150**
CA30	0	0	10	10	10	**30**
CA31	0	30	30	30	30	**120**
CA32	1	1	1	1	1	**5**
Total	**31**	**61**	**71**	**71**	**71**	**305**
TOTAL works	**4,577**	**1,131**	**1,141**	**1,141**	**1,141**	**9,131**

Operating Costs (OPEX)

Once installed, the OPEX costs for PQ monitors are negligible as there is no incremental inspection cost and minimal maintenance or replacement costs. As such, no OPEX costs have been included in this NPV analysis.

Energex however does attempt to address any voltage or PV related QoS queries via operational expenditures with network solutions such as LV load balancing, transformer tap changing etc. before exploring options that require capital expenditures. These OPEX costs are captured under separate categories. In addition, communication and ICT management costs are managed centrally, as part of operational technology programs.

Benefits (Avoided Expenditure)

Benefits associated with extended PQ monitoring capability through the Option 3 program have been modelled in this analysis as 'additional cost' in Options 1 and 2, therefore demonstrating that a comparative saving can be observed in Option 3.

Several expenditure categories have been identified based on the extension of PQ monitoring capability, and each is outlined in the following sections, with their total associated annual values summarised in Table 13.

For each avoided expenditure category, the annual value associated with installing additional PQ monitors is scaled in proportion to the number of monitors installed to date. For example, in Year 1 of the program, 750 PQ monitors out of a total 4,230 are installed under Option 3. Therefore ~18% of the total value shown in Table 13 is incurred in Year 1. By Year 5 when the program has been completed, 100% of the value is incurred annually, and in every year thereafter.

Table 13: Summary of Avoided Expenditure Categories

Avoided Expenditure Category	Total Value ($/year)
Modelling for Small-Medium Connections	$230,400
Modelling for Large Connection Customers	$72,000
Installation of Portable / Short-Term PQ Data Recorders	$60,800
Savings on QoS Investigations	$134,400
Network Augmentation Savings	$592,000
Customer Compliance Claims Savings	$11,000
Voltage Regulator Setting Savings	$75,842
Distribution Transformer Tap Changer Savings	$70,762
Total	**$1,247,204**

Avoided Expenditure – Modelling for Small-Medium Connections

Extra network modelling time is required to validate models for small-medium connections in the absence of PQ monitors:

- It has been estimated that with installation of PQ monitors on a further 8% of distribution feeders, that savings could be achieved in 8% of the approximately 1,500 Work Requests (WRs) received every year for new small-medium connections, as PQ monitor data will be available for use in place of extensive model validation processes.
- Consultation with network planning teams indicates that 8-24 hours of additional modelling time is typically required for connections with additional network complexities and without PQ data available, at a rate of $120/hour. Considering 120 WRs/year and an average 16 hours/job, this results in an additional cost of $230,400/year for Options 1 and 2 compared to Option 3.

Avoided Expenditure – Modelling for Large Connection Customers

Additional cost is incurred for network modelling and validation for large connection customers. Given the absence of PQ monitors on the MV network where large customers tend to connect, PQ monitor data from LV networks is typically utilised to estimate or make assumptions on the PQ health of the MV network where the large connection applications are received.

- It was assumed that savings for network modelling for large customers on the MV network could be made in 50% of cases out of a conservative annual average of 48 connection applications, based on the placement of PQ monitors in the MV network in Option 3.
- It was conservatively assumed that around 25 hours of additional resource for temporary network data collection (10 hours) and modelling time (15 hours) could be saved with Option 3. At a rate of $120/hour, considering 24 cases per year, this results in an additional cost of $72,000/year for Options 1 and 2 compared to Option 3.

Avoided Expenditure – Installation of Portable / Short-Term PQ Data Recorders

In some cases, for connection application or enquiries to the Energex network, portable short-term PQ data recorders must be installed to collect data for network planning purposes or checking the

PQ compliance, as there is no historical record of PQ data and no way to make accurate assumptions about the health of the network.

- Based on information from field investigations, it was assumed that an average of 40 uses of short-term recorders per year could be avoided through the PQ monitoring program proposed under Option 3. Using an average of 16 hours for travel time and installation of portable monitors, and a rate of $95/hour for field staff, this results in an additional cost of $60,800/year for Options 1 and 2 compared to Option 3.

Avoided Expenditure – Savings on QoS Investigations

Having a PQ monitor in place introduces substantial savings to QoS investigations for Energex, due to factors such as reduced travel times and simplified diagnostic modelling requirements when responding to customer enquiries and complaints. PQ information from the additional monitors can also be utilised to estimate the state of PQ health of the MV network, improving the efficiency of MV network QoS responses.

- The recommended average cost of one QoS job without a PQ monitor is $4,646 in urban areas and $5,800 for rural areas. As cost savings associated with PQ monitor use vary between feeders and QoS job requirements, it was assumed that a 30% saving could be achieved on QoS jobs for all feeder categories where a PQ monitor was in place. Using the lower value of $4,646 for an urban QoS job for conservatism, it was assumed that an approximate saving of $1,400 could be made for all feeder categories.
- The average annual number of QoS jobs is around 1,200. It was assumed that savings could be applied to 8% of these annual QoS jobs, or 95 jobs. This results in an additional cost of $134,400 per year for Options 1 and 2 compared to Option 3.

Avoided Expenditure – Network Augmentation Savings

Network augmentation savings are realised in cases where PQ monitors can be used to either reduce the cost of network augmentation needed to address voltage regulation issues, by delivering capital savings due to changes to project scope, or by deferring or cancelling projects entirely. It is difficult to estimate the exact impact of PQ monitors on reactive and/or proactive distribution network augmentation, due to the complexity and specifics of planning methods, the various potential sources of savings from PQ data use, and the various different approaches that can be taken to address voltage regulation issues.

- Based on Energex's historical spend, a flat allowance for customer initiated reactive augmentation work of around $11.4M per annum was included in Energex's Augex capital spend for distribution works. It is assumed that a 3% saving can be achieved commensurate with the level of monitoring and the expected increases in voltage complaints over the next five years, and therefore an annual saving of around $342,000 is considered feasible.
- Based on an example of proactive voltage regulator project, deferred through use of PQ monitoring data resulting in Augex savings, it is assumed that at least one voltage regulator project can be avoided annually for each of Energex regions (Northern and Southern). This results in an additional cost of $250,000 per year for Options 1 and 2 compared to Option 3.
- The total estimated additional cost of $592,000 is still considered conservative as proactive MV/LV augmentation work might also include other solutions such as re-conductoring and installation of new or upgraded distribution transformers, and this saving also does not account for savings from sources such as avoided network modelling times or savings associated with the transition from MDIs to PQ monitors.

Avoided Expenditure – Customer Compliance Claims Savings

The extension of PQ monitoring capability will provide Energex with a greater ability to monitor PQ non-compliance and address voltage issues which might cause damage to customer equipment, thereby reducing the volume of payment for customer claims due to equipment damage. Customers make a large number of claims annually for damaged equipment that they suspect failed due to network issues. These customer claims can be checked against PQ monitor data to see if the network was non-compliant at the time of the event leading to the claim. In several cases, data from PQ monitors have confirmed that the network was compliant, meaning that Energex is not required to pay out the claims, generating savings.

- An annual saving of $11,000 for Option 3 has been assumed, based on a 2% saving on estimated average annual payments by Energex to customers for damage claims related to network power quality issues.

Avoided Expenditure – Voltage Regulator Setting Savings

PQ monitors installed downstream of voltage regulators are used to verify network models for voltage regulator settings and also for detection of failed regulators and/or changes required in regulator settings. Use of PQ monitors therefore enables Energex to reduce the labour requirement associated with manually checking or adjusting voltage regulator settings across the network in response to QoS or other PQ issues.

- It was estimated that labour works could be avoided for 3% of the total population of 496 voltage regulators, and 2% of the total population of 288 zone substations under Option 3. This estimation is based on number of factors, including penetration levels of PV systems, feeder topologies and technical characteristics, loading and voltage profiles, location of voltage regulators, and the technical characteristics of both these and controlled feeder sections. In addition, there is an increasing trend of Energex feeders and zone substations with reverse power flows affecting settings of existing line and zone substation voltage regulators. For example, based on the forecasting minimum demand data it is estimated that 278 distribution feeders (or 13% of total population of Energex' distribution feeders) and verified 37 zone substations (15%) in Energex network have reverse power flows.
- A labour saving of $4,536 has been applied in each case, based on a typical work time of around 38 hours at a rate of $120/hour. Taking into account the unit populations, this results in an additional cost of $75,842 per year for Options 1 and 2 compared to Option 3.

Avoided Expenditure – Distribution Transformer Tap Changer Savings

Similarly, use of PQ monitors enables Energex to reduce the labour requirement associated with adjusting distribution transformer tap settings. PQ monitors installed on distribution transformers are used to verify network models for tap changers' positions and also for detection of overloading and inappropriate tap settings.

- Energex network has extensive penetration of PV systems in LV networks controlled by distribution transformers with different tap settings (with 5 or 7 steps between buck, neutral and boost positions). On an annual basis, around 9% of customer QoS complaints are due to voltage regulation issues (besides the ones arising directly from solar PV penetration) against the distribution transformers where there are no PQ monitors (109). In order to rectify the voltage issues raised by one QoS complaint, more than one transformer will require tap changing. It is assessed that labour works could be avoided on approximately 15% of these transformers if the need for transformer tap changers were identified proactively by the PQ monitors. This equates to cost saving on around 0.03% of the total population of 52,000 distribution transformers.

- Using the same labour saving of $4,536 as applied for voltage regulator setting savings, this results in an additional cost of $70,762 per year for Options 1 and 2 compared to Option 3.

Results

Based on each of the costs and benefits (modelled as additional costs incurred in Option 2) described in the previous sections, the Net Present Value (NPV) of each option was calculated. Table 14 outlines the results of NPV analysis for both options, displaying the CAPEX and Additional Costs incurred by each option over the study period, discounted at the Regulated Real Pre-Tax Weighted Average Cost of Capital (WACC) rate of 2.62% over a 20-year study period.

Despite the lower capital cost of Options 1 and 2 without the PQ monitoring program, the additional costs incurred compared to Option 3 results in Option 3 being more cost-effective.

Table 14: Net Present Value of Options

Option	CAPEX PV ($M)				Additional Cost PV ($M)	NPV ($M)	Rank
	PQ Monitoring	Customer Remediation	PV Augmentation	Total			
Option 1 – Do Nothing	-	(15.36)	(10.65)	**(26.01)**	(17.23)	**(43.23)**	**3**
Option 2 – Augmentation Works Only	-	(11.81)	(10.65)	**(22.46)**	(17.23)	**(39.69)**	**2**
Option 3 – Full Program (Recommended)	(15.78)	(11.81)	(10.65)	**(38.24)**	-	**(38.24)**	**1**

Additionally, we can examine the PQ monitoring component of Option 3 alone to show that the program by itself is also NPV positive.

Considering the benefits associated with Option 3 as a positive 'savings' cashflow rather than a lower comparative cost as in Table 14, the results in Table 15 demonstrate that the PQ monitoring component of Option 3 alone has a positive NPV of $1.44M. The Benefit Cost Ratio (BCR) of this program component was calculated as 1.09, meaning that for each dollar spent in funding the Option 3 PQ monitoring CAPEX, slightly more than the same value is generated in cost savings across the Energex network.

Table 15: Net Present Value of Option 3 PQ Monitoring Component

Option	CAPEX ($M)	Savings ($M)	NPV ($M)	BCR
Option 3	(15.78)	17.23	1.44	1.09

3.4 Scenario Analysis

3.4.1 Sensitivities

Sensitivity analysis was considered on the following variables:

- **PQ Program CAPEX:** Sensitivities of +/- 20% were considered on the capital cost associated with extension of PQ monitoring capability.

- **Remediation & Augmentation Programs CAPEX:** Sensitivities of +/- 20% were considered on the capital cost associated with the customer voltage remediation and solar PV augmentation programs.
- **Avoided Expenditure:** Sensitivities of +/- 20% were considered on the sources of avoided expenditure associated with Option 3 compared to Options 1 and 2. Due to the number of expenditure categories considered, and the uncertainties associated with each, sensitivity was considered on the total value of savings rather than on each individual category.

The results of sensitivity analysis are shown in Table 16. Option 3 was the least cost option for all sensitivity scenarios tested except where the value of avoided expenditure was reduced by 20%, or where the PQ Program CAPEX was increased by 20%.

Efforts have been made to ensure that assumptions relating to avoided expenditure are conservative wherever possible, meaning that the -20% case for avoided expenditure is considered unlikely.

Additionally, as the PQ Program CAPEX is based on historical patterns of expenditure, and represents a 31% reduction in cost when compared to 2015-20 AER reset (see Appendix H for further detail), a scenario where the program cost increases by 20% is also considered unlikely.

Table 16: Results of Sensitivity Analysis

NPV ($M)	Base Scenario	Remediation & Augmentation CAPEX		PQ Program CAPEX		Avoided Expenditure	
		-20%	20%	-20%	20%	-20%	20%
Option 1 – Do Nothing	(43.23)	(38.03)	(48.43)	(43.23)	(43.23)	(39.79)	(46.68)
Option 2 – Augmentation & Remediation Works Only	(39.69)	(35.20)	(44.18)	(39.69)	(39.69)	(36.24)	(43.13)
Option 3 – Full Program (Recommended)	(38.24)	(33.75)	(42.74)	(35.09)	(41.40)	(38.24)	(38.24)
Least Cost Option	*Option 3*	*Option 3*	*Option 3*	*Option 3*	*Option 2*	*Option 2*	*Option 3*

3.4.2 Value of Regret Analysis

In terms of selecting a decision pathway of 'least regret', Option 3 will allow for better management of PQ issues, more efficient and targeted investment into network capital programs to address identified issues, and the ability to predict and respond proactively to issues before they present safety or Quality of Supply issues.

While Option 3 presents the highest CAPEX of the considered options, the significant benefits provided by enhanced PQ monitoring mean it has the lowest NPV of the options considered and make it the least regret option. This program only seeks extension of existing capability in line with current expenditure and does not unnecessarily accelerate spending in line with concerns raised through customer engagement about network costs. Without extension of PQ monitoring capability, Energex will lose access to another five years of data, particularly limiting its future ability to understand the operation of MV network power flows. Extension of PQ monitoring is essential for future network optimisation.

This proposal acknowledges the future potential for use of smart-meter data to model PQ parameters and network flows, through EQL's engagement with ARENA in the SEA program. However, this technology is not suitable to provide Energex with the required monitoring capability at this stage in time. Without extension of PQ monitoring capability, Energex will lose access to another five years of extended data monitoring, particularly limiting its future ability to understand the operation of MV network power flows. The potential for network monitoring through options such as wide-spread customer smart-meter monitoring should be considered again in future proposals, when the technology is more advanced.

3.5 Qualitative comparison of Identified Options

3.5.1 Advantages and disadvantages of each option

Table 17 details the advantages and disadvantages of each option considered.

Table 17: Qualitative Assessment of Options – Power Quality Monitoring

Options	Advantages	Disadvantages
Option 1 – Do Nothing	• Capital savings from excluding monitoring programs	• Additional costs incurred to standard operations due to lack of PQ monitoring in the wider Energex network • Does not support Energex or EQL strategies for modernising the grid or encouraging DER uptake • Lack of planned approach means that emergency remediation and augmentation works must be carried out to address compliance and safety concerns
Option 2 – PV Augmentation and remediation works only	• Capital savings from excluding monitoring programs	• Additional costs incurred to standard operations due to lack of PQ monitoring in the wider Energex network • Does not support Energex or EQL strategies for modernising the grid or encouraging DER uptake
Option 3 – Full Program: Extend PQ monitoring capability and perform augmentation and remediation works	• Better ability to manage and monitor PQ in the network, and thereby reduce QoS complaints and reduce costs associated with service callouts • Drive efficient network investment through greater ability to model and monitor network • Strategic alignment with internal strategies, customer engagement, AEMC suggested actions, and Queensland Government policy.	• Higher CAPEX associated due to installation of PQ monitors.

In addition, based on historical installation trends and forecast connection applications, the penetration of Solar PV and other DERs in the Energex network is only going to increase over time. This is in line with the Queensland Government renewable energy target of 50% by 2030, as well as findings from wider customer engagement programs. At the same time, implementation of smart grid technologies is increasingly common across the network on both the customer and network side. The key regret in this case would be the inability of the Energex network to accommodate the needs to customers in connecting renewable generation to enable electricity cost savings.

Implementation of the preferred Option 3 will see the extension of current PQ monitoring capability, giving Energex improved visibility of all levels of the network and an enhanced understanding of the impacts of increasing DER penetration. The AEMC's recent publication on "Integrating Distributed Energy Resources for the Grid of the Future" outlined the following two key recommendations directly related to increased LV network monitoring:

- DNSPs should continue to develop business cases for improvement of modelling and monitoring of their LV networks.
- DNSPs, in collaboration with industry and consumer representatives, should identify additional meter data that should be collected and made available in order to support LV network visibility, in a manner that maximises net benefits to consumers.

This program is aligned with these AEMC recommendations and prepares Energex for the future where smart grid technologies are ubiquitous. Implementation of Option 3 will allow for better management of PQ issues, more efficient and targeted investment into network capital programs to address identified issues, and the ability to predict and respond proactively to issues before they present safety or Quality of Supply issues.

3.5.2 Alignment with network development plan

The preferred option aligns with the Asset Management Objectives in the Distribution Annual Planning Report. In particular it manages risks, performance standards and asset investment to deliver balanced commercial outcomes while modernising the network to facilitate access to innovative technologies.

3.5.3 Alignment with future technology strategy

This program is aligned strongly with the Future Grid Roadmap and Intelligent Grid Technology Plan, as it will allow Energex to improve their understanding of two-way energy flows in LV networks, facilitating efficient investment decision-making to address compliance and safety issues, and enabling connection of DERs to the LV grid in a safe and effective manner. Beyond 2020, together with other initiatives, the PQ monitoring program will enable application of intelligent grid solutions including planning and management of micro-grids, and development of technology platforms for monitoring and analysing of distributed energy resources.

3.5.4 Risk Assessment Following Implementation of Proposed Option

Table 18 outlines the risk assessment for the Energex network following implementation of the proposed Option 3 program.

Table 18: Risk assessment showing risks mitigated following Implementation

Risk Scenario	Risk Type	Consequence (C)	Likelihood (L)	Risk Score	Risk Year
Multiple customers' supply voltage is outside the regulated range (+10/- 6% of 230 V). These unregulated voltages lead to significant damage to customer equipment resulting in significant impact on any restoration or planned works equating to business cost >$500,000.	Business	(Original) 4 *(Significant impact on any restoration or planned works equating to business cost >$500,000)* (Mitigated) 4 *(Significant impact on any restoration or planned works equating to business cost >$500,000)*	 3 *(Unlikely)* 2 *(Very Unlikely)*	 **12** ***(Moderate Risk)*** **8** ***(Low Risk)***	2020
Inability to monitor and manage voltage in the regulated range (+10/- 6% of 230 V) and AFLC signal levels, particularly in areas with high Solar PV penetration and long low voltage circuit lengths, potentially leads to breaching regulated standards and an improvement notice being issued by the regulator.	Legislative	(Original) 4 *(Improvement notice issued by regulator)* (Mitigated) 4 *(Improvement notice issued by regulator)*	 3 *(Unlikely)* 2 *(Very Unlikely)*	 **12** ***(Moderate Risk)*** **8** ***(Low Risk)***	2020
Inability to monitor and manage supply voltage outside of the regulated range (+10/- 6% of 230 V) and AFLC signal levels, particularly in areas with high Solar PV penetration and long low voltage circuit lengths, potentially results in an increase to customer light flicker and/or appliance/ network equipment damage. This results in disruption to businesses and essential services.	Customer	(Original) 3 *(Disruption to a large business or essential service)* (Mitigated) 3 *(Disruption to a large business or essential service)*	 4 *(Likely)* 3 *(Unlikely)*	 **12** ***(Moderate Risk)*** **9** ***(Low Risk)***	2020
Inability to monitor and manage voltage and AFLC signal levels, particularly in areas with high Solar PV penetration, potentially leads to poor network planning and business investment decisions. Energex is unable to deliver strategic initiatives related to optimal asset design with respect to new technologies without incurring costs resulting in significant cost premium (>50% of estimates)	Customer	(Original) 3 *(Significant cost premium (>50% of estimates) to deliver agreed strategic initiatives)* (Mitigated) 3 *(Significant cost premium (>50% of estimates) to deliver*	 4 *(Likely)* 3 *(Unlikely)*	 **12** ***(Moderate Risk)*** **9** ***(Low Risk)***	2020

Risk Scenario	Risk Type	Consequence (C)	Likelihood (L)	Risk Score	Risk Year
to deliver agreed strategic initiatives.		*agreed strategic initiatives)*			
Customer supply voltage is outside the regulated range (+10/- 6% of 230 V). Inadvertent contact with customer appliance or network equipment with very high voltages results in a single fatality.	Safety	(Original) 5 *(Single Fatality)* (Mitigated) 4 *(Multiple Serious Injuries)*	 2 *(Very Unlikely)* 2 *(Very Unlikely)*	 **10** ***(Low Risk)*** **8** ***(Low Risk)***	2020
Inability to monitor and manage supply voltage outside of the regulated range (+10/- 6% of 230 V) and AFLC signal levels, in areas with high Solar PV penetration and long low voltage circuit lengths results in abnormal network configuration while reactive work is undertaken to rectify issues	Business	(Original) 3 *(Abnormal network configuration)* (Mitigated) 3 *(Abnormal network configuration)*	 2 *(Very Unlikely)* 1 *(Almost No Likelihood)*	 **6** ***(Low Risk)*** **3** ***(Very Low Risk)***	2020

4 Recommendation

4.1 Preferred option

The preferred option is Option 3, which includes the extension and upgrading of Energex's existing PQ monitoring capability, alongside traditional customer voltage remediation works and solar PV augmentation works necessary to respond to areas of non-compliant network. Extending the PQ monitoring capability to a further 8% of distribution transformers unlocks significant potential benefits for Energex. The ability to better monitor, plan, and address PQ issues in the network will allow the distribution network to cope with the rapid uptake of solar PV and other distributed energy resources. This option is aligned with EQL's PQ strategies, future technology strategies, and customer engagement.

4.2 Scope of preferred option

The scope of works planned for Option 3 is outlined in Table 19, and highlights the forecast programs of replacement or works under each of the three main initiatives and each of their component programs.

Table 19: Scope of Works for Preferred Option 3

Program	Units Replaced / Installed					
	FY 20/21	FY 21/22	FY 22/23	FY 23/24	FY 24/25	Total
	PQ Monitoring					
CA15	250	250	250	250	250	**1,250**
CA44	250	250	250	250	250	**1,250**
CA48	250	250	250	250	250	**1,250**
CA29	0	120	120	120	120	**480**
CA55	3,596	0	0	0	0	**3,596**
Total	**4,346**	**870**	**870**	**870**	**870**	**7,826**
	Customer Voltage Remediation					
CA33	100	100	100	100	100	**500**
CA50	100	100	100	100	100	**500**
Total	**200**	**200**	**200**	**200**	**200**	**1,000**
	Solar PV Augmentation					
CA46	30	30	30	30	30	**150**
CA30	0	0	10	10	10	**30**
CA31	0	30	30	30	30	**120**
CA32	1	1	1	1	1	**5**
Total	**31**	**61**	**71**	**71**	**71**	**305**
TOTAL works	**4,577**	**1,131**	**1,141**	**1,141**	**1,141**	**9,131**

The annual CAPEX associated with Option 3 is outlined in Table 20, in real $2018/19 dollars. The total CAPEX spend planned for the program in the next regulatory period is $42,948,861.

Table 20: Planned Annual CAPEX Spend Under Option 3 Program

Program	Planned Annual CAPEX Spend (Real 2018/19 $)					
	FY 20/21	FY 21/22	FY 22/23	FY 23/24	FY 24/25	Program Total
	PQ Monitoring					
CA15	$721,331	$753,087	$753,049	$753,084	$753,076	**$3,733,628**
CA44	$1,270,677	$1,270,692	$1,270,674	$1,270,707	$1,270,673	**$6,353,423**
CA48	$570,850	$570,858	$570,852	$570,862	$570,849	**$2,854,271**
CA29	$0	$825,255	$825,276	$825,292	$825,304	**$3,301,126**
CA55	$1,411,788	$0	$0	$0	$0	**$1,411,788**
Total	**$3,974,645**	**$3,419,892**	**$3,419,851**	**$3,419,945**	**$3,419,903**	**$17,654,236**
	Customer Voltage Remediation					
CA33	$635,072	$635,058	$635,050	$635,069	$635,059	**$3,175,308**
CA50	$2,017,832	$2,017,821	$2,017,822	$2,017,825	$2,017,827	**$10,089,127**
Total	**$2,652,904**	**$2,652,879**	**$2,652,871**	**$2,652,895**	**$2,652,886**	**$13,264,435**
	Solar PV Augmentation					
CA46	$1,995,040	$1,995,032	$1,995,049	$1,995,023	$1,977,806	**$9,957,950**
CA30	$0	$0	$242,729	$242,730	$242,729	**$728,187**
CA31	$0	$260,899	$260,913	$260,904	$260,906	**$1,043,622**
CA32	$60,092	$60,084	$60,085	$60,087	$60,084	**$300,431**
Total	**$2,055,132**	**$2,316,016**	**$2,558,776**	**$2,558,743**	**$2,541,524**	**$12,030,190**
TOTAL	**$8,682,681**	**$8,388,787**	**$8,631,498**	**$8,631,583**	**$8,614,312**	**$42,948,861**

Appendix A. References

Note: Documents which were included in Energy Queensland's original regulatory submission to the AER in January 2019 have their submission reference number shown in square brackets, e.g. Energy Queensland, *Corporate Strategy [1.001], (31 January 2019).*

AEMC, *Integrating Distributed Energy Resources for the Grid of the Future, Economic Regulatory Framework Review,* (26 September 2019).

Energex, *Distribution Annual Planning Report (2018-19 to 2022-23) [7.050]*, (21 December 2018).

Energy Queensland, *Asset Management Overview, Risk and Optimisation Strategy [7.025]*, (31 January 2019).

Energy Queensland, *Customer Quality of Supply Strategy [7.047],* (31 January 2019).

Energy Queensland, *Corporate Strategy [1.001],* (31 January 2019).

Energy Queensland, *Future Grid Roadmap [7.054],* (31 January 2019).

Energy Queensland, *Intelligent Grid Technology Plan [7.056],* (31 January 2019).

Energy Queensland, *Low Voltage Network Monitoring Strategy [7.080],* (31 January 2019).

Energy Queensland, *Network Risk Framework*, (October 2018).

Appendix B. Acronyms and Abbreviations

The following abbreviations and acronyms appear in this business case.

Abbreviation or acronym	Definition
ACR	Automatic Circuit Recloser
ADMS	Advanced Distribution Management System
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
AFLC	Audio Frequency Load Control
AUGEX	Augmentation Expenditure
CAPEX	Capital Cost
DAPR	Distribution Annual Planning Reports
DER	Distributed Energy Resource
DERMS	Distributed Energy Resources Management System
DNSP	Distribution Network Service Provider
DT	Distribution Transformer
EQL	Energy Queensland
EV	Electric Vehicles
KRA	Key Result Areas
LED	Light Emitting Diode
LV	Low Voltage
MAIFIe	Momentary Average Interruption Event Frequency Index event
MDI	Maximum Demand Indicator
MSS	Minimum Service Standards
MV	Medium Voltage
Next Regulatory Control Period	The regulatory control period 2020/21 to 2024/25
NER	National Electricity Rules
NPV	Net Present Value
OH	Overhead
OLTC	On-Load Tap Changer
OPEX	Operating Cost
PCBU	Person in Control of a Business or Undertaking
PQ	Power Quality
PV	(Solar) Photovoltaic
QLD	Queensland
QoS	Quality of Supply
RIN	Regulatory Information Notice

Abbreviation or acronym	Definition
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	System Control and Ancillary Data Acquisition
STPIS	Service Target Performance Incentive Scheme
UG	Underground
WACC	Weighted Average Cost of Capital
WR	Work Request

Appendix C. Alignment with the National Electricity Rules (NER)

The table below details the alignment of this proposal with the NER capital expenditure requirements as set out in Clause 6.5.7 of the NER.

Table 21: Alignment with NER

Capital Expenditure Requirements	Rationale
6.5.7 (a) (2) **The forecast capital expenditure is required in order to comply with all applicable regulatory obligations or requirements associated with the provision of standard control services**	As indicated in *Table 2: Compliance obligations related to this proposal*, this proposal ensures that safety obligations, reliability obligations and protection requirements are met by providing an appropriate, economically efficient program of works to ensure that the instance and impact of Power Quality issues can be managed effectively. Without this program, these obligations would be at risk of being breached.
6.5.7 (a) (3) **The forecast capital expenditure is required in order to:** **(iii) maintain the quality, reliability and security of supply of supply of standard control services** **(iv) maintain the reliability and security of the distribution system through the supply of standard control services**	This program of work directly addresses Power Quality issues which impact the quality of supply of standard control services. Network augmentation and remediation works and extended PQ monitoring capability are used to better analyse, understand, and respond to quality of supply issues which impact customer service and can result in non-compliance.
6.5.7 (a) (4) **The forecast capital expenditure is required in order to maintain the safety of the distribution system through the supply of standard control services.**	This proposal ensures that the safety or the distribution system is maintained by reducing the risk associated with power quality and voltage non-compliance issues.
6.5.7 (c) (1) (i) **The forecast capital expenditure reasonably reflects the efficient costs of achieving the capital expenditure objectives**	The options considered in this proposal take into account the need for efficiency in delivery and use historical programs of work as a basis for cost estimates. The preferred option has utilised a delivery approach that provides for bundling of work in terms of both timing and geography to enable a lower cost delivery. Specialised contractors are utilised as appropriate to ensure that costs are efficiently managed through market testing. Cost performance of the program will be monitored to ensure that cost efficiency is maintained. The unit costs that underpin our forecast have also been independently reviewed to ensure that they are efficient (Attachments 7.004 and 7.005 of our initial Regulatory Proposal).
6.5.7 (c) (1) (ii) **The forecast capital expenditure reasonably reflects the costs that a prudent operator would require to achieve the capital expenditure objectives**	The prudency of this proposal is demonstrated through the options analysis conducted. The prudency of our CAPEX forecast is demonstrated through the application of our common frameworks put in place to effectively manage investment, risk, optimisation and governance of the Network Program of Work. An overview of these frameworks is set out in our Asset Management Overview, Risk and Optimisation Strategy (Attachment 7.026 of our initial Regulatory Proposal).

Appendix D. Mapping of Asset Management Objectives to Corporate Plan

This proposal has been developed in accordance with our Strategic Asset Management Plan. Our Strategic Asset Management Plan (SAMP) sets out how we apply the principles of Asset Management stated in our Asset Management Policy to achieve our Strategic Objectives.

Table 1: “Asset Function and Strategic Alignment” in Section 1.4 details how this proposal contributes to the Asset Management Objectives.

The Table below provides the linkage of the Asset Management Objectives to the Strategic Objectives as set out in our Corporate Plan (Supporting document 1.001 to our Regulatory Proposal as submitted in January 2019).

Table 22: Alignment of Corporate and Asset Management objectives

Asset Management Objectives	Mapping to Corporate Plan Strategic Objectives
Ensure network safety for staff contractors and the community	**EFFICIENCY** **Operate safely as an efficient and effective organisation** Continue to build a strong safety culture across the business and empower and develop our people while delivering safe, reliable and efficient operations.
Meet customer and stakeholder expectations	**COMMUNITY AND CUSTOMERS** **Be Community and customer focused** Maintain and deepen our communities’ trust by delivering on our promises, keeping the lights on and delivering an exceptional customer experience every time
Manage risk, performance standards and asset investments to deliver balanced commercial outcomes	**GROWTH** **Strengthen and grow from our core** Leverage our portfolio business, strive for continuous improvement and work together to shape energy use and improve the utilisation of our assets.
Develop Asset Management capability & align practices to the global standard (ISO55000)	**EFFICIENCY** **Operate safely as an efficient and effective organisation** Continue to build a strong safety culture across the business and empower and develop our people while delivering safe, reliable and efficient operations.
Modernise the network and facilitate access to innovative energy technologies	**INNOVATION** **Create value through innovation** Be bold and creative, willing to try new ways of working and deliver new energy services that fulfil the unique needs of our communities and customers.

Appendix E. Risk Tolerability Table

Network Risks - *Risk Tolerability Criteria and Action Requirements*				
Risk Score	Risk Descriptor	Risk Tolerability Criteria and Action Requirements		
30 – 36	***Intolerable*** *(stop exposure immediately)*			
24 – 29	***Very High Risk***	***ALARP** Risk in this range managed to As Low As Reasonably Practicable	**Executive Approval** (required for continued risk exposure at this level)	May require a full Quantitative Risk Assessment (QRA) Introduce new or changed risk treatments to reduce level of risk Periodic review of the risk and effectiveness of the existing risk treatments
18 – 23	***High Risk***	***ALARP** Risk in this range managed to As Low As Reasonably Practicable	**Divisional Manager Approval** (required for continued risk exposure at this level)	Introduce new or changed risk treatments to reduce level of risk Periodic review of the risk and effectiveness of the existing risk treatments
11 – 17	***Moderate Risk***	***ALARP** Risk in this range managed to As Low As Reasonably Practicable	**Group Manager / Process Owner Approval** (required for continued risk exposure at this level)	Introduce new or changed risk controls or risk treatments as justified to further reduce risk Periodic review of the risk and effectiveness of the existing risk treatments
6 – 10	**Low Risk**	***ALARP** Risk in this range managed to As Low As Reasonably Practicable	**Group Manager / Process Owner Approval** (required for continued risk exposure at this level)	Introduce new or changed risk controls or risk treatments as justified to further reduce risk Periodic review of the risk and effectiveness of the existing risk treatments
1 to 5	***Very Low Risk***	***ALARP** Risk in this range managed to As Low As Reasonably Practicable	No direct approval required but evidence of ongoing monitoring and management is required	*Periodic review of the risk and effectiveness of the existing risk treatments*

SFAIRP
Risks in this area to be mitigated So Far as is Reasonably Practicable

Figure 7: A Risk Tolerability Scale for evaluating Semi-Quantitative risk score

Appendix F. Reconciliation Table

Reconciliation Table Conversion from $18/19 to $2020	
Business Case Value	
(M$18/19)	$42.95
Business Case Value	
(M$2020)	$44.67

Appendix G. Supporting Information on Uptake of Solar PV

This appendix provides additional supporting information regarding the uptake of solar PV in Energex networks. This information was also used to develop the program of work presented in this proposal.

Historical Growth

Energex has experienced rapid growth in Solar PV over the last five years with 358,935 connections at the end of June 2018, equating to a total capacity of 1,388MW. This is the highest per-capita capacity of rooftop solar worldwide and makes residential PV equivalent to the fourth largest generator of electricity in Queensland. The challenge for Energex is to incorporate the evolving requirements of customers into business as usual activities.

At the LV level, Energex networks have recorded sustained growth in connection of customers installing Solar PV systems with a penetration rate of approximately 40%.

Figure 8 shows the increase in connections since January 2012. The growth rate has been approximately 34% per annum in the last 5 years and is projected to be 14% in the next 7 years.

One of the key power quality challenges addressed in the EQL's PQ strategies arises from the high penetration of customer PV systems on all parts of the network.

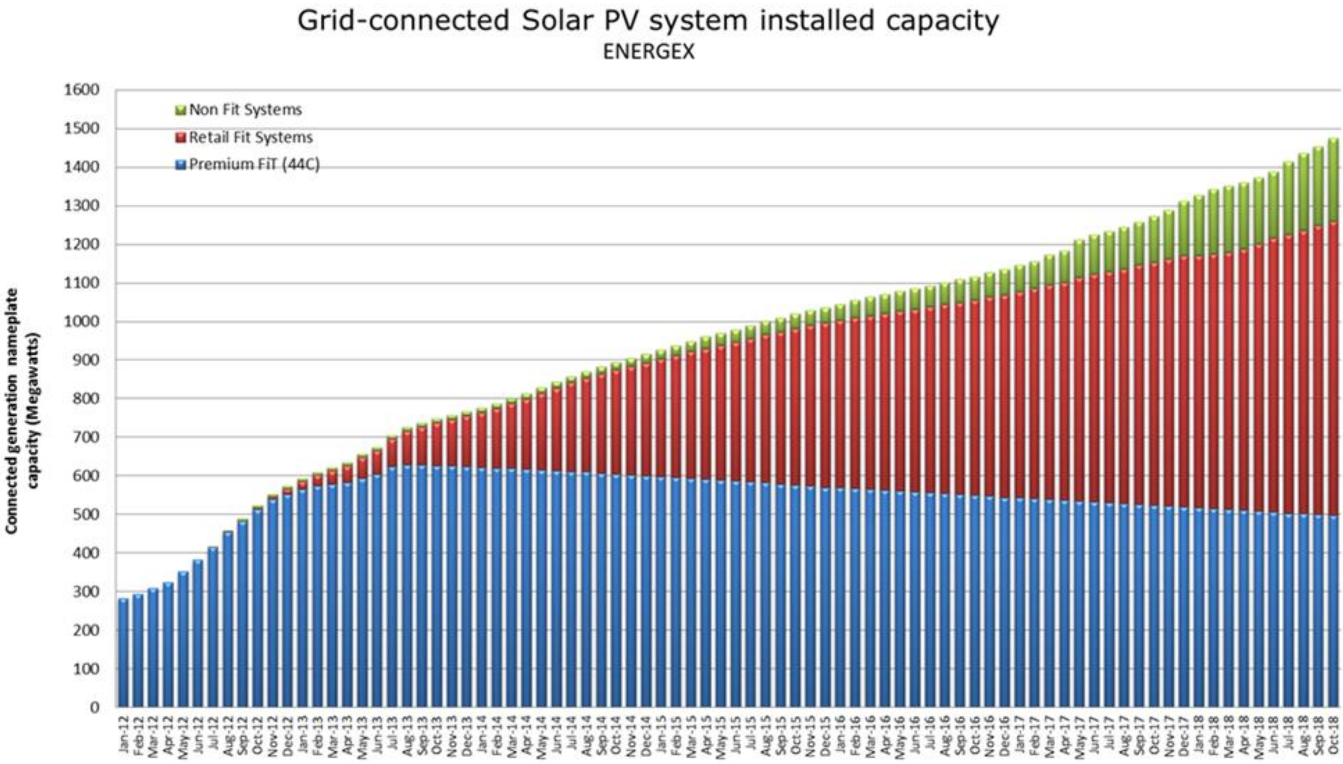

Figure 8: Historical Growth of Energex Solar PV Connections

Projected Growth During the Next Regulatory Period

Table 23 provides a preliminary forecast of the expected cumulative growth in the number of customer connections and inverter capacity for systems ≤5kW to the end of the next regulatory control period 2020-25. The capacity forecast assumes an average inverter rating of 3kW per installation. This growth is assumed to occur in predominantly existing areas of Solar PV penetration, with an overall effective increase in connections of around 70% compared to 2017-18 levels.

This forecast assumes current growth rates of in excess of 3,000 inverters per month. This is slightly lower than the previous regulatory control period 2010-15 due to the elimination of the feed-in tariff (FiT). These projected rates are only indicative and not based on any detailed modelling. The forecast does not factor in the influence of energy storage systems as their uptake is considered low within the current regulatory control period without further reduction in storage costs or incentive arrangements.

Table 23: Forecast of Total Solar PV Connections and Capacity Growth 2020-25

	Actuals	Forecast						
	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25
Number of connections	358,935	411,510	457,779	502,514	546,688	590,273	630,281	665,366
Installed capacity (MW) for inverters <5kW	1,429	1,638	1,822	2,001	2,176	2,350	2,509	2,649

It is very difficult to predict with any confidence Solar PV uptake rates out as far as 2028 given the range of influencing factors, including: dependence on tariff incentives, cost of systems, customer behaviour in response to the rising price of electricity; solar industry marketing and sales campaigns (including energy storage ready), and Retailer's offering bonus deals.

The current and projected growth of residential solar for Energex is shown in Figure 3. The three scenarios assume that the cost of Solar PV systems, particularly the larger systems, have stabilised and the price of electricity from the grid is stabilised or reducing in real terms for customers. These two factors make it more likely that solar PV connections will decrease rather than increase.

There is the possibility that further disruption through energy storage technologies such as standalone batteries or electric vehicle batteries integrated into existing solar PV systems could spur growth above the high scenario in the period to 2028, but at this stage, it is not considered likely enough to include as a scenario. Even if this were to occur, it is likely that these technologies will mitigate a lot of the existing impacts on voltage regulation if the appropriate network policies and tariffs are implemented to control power export to the grid.

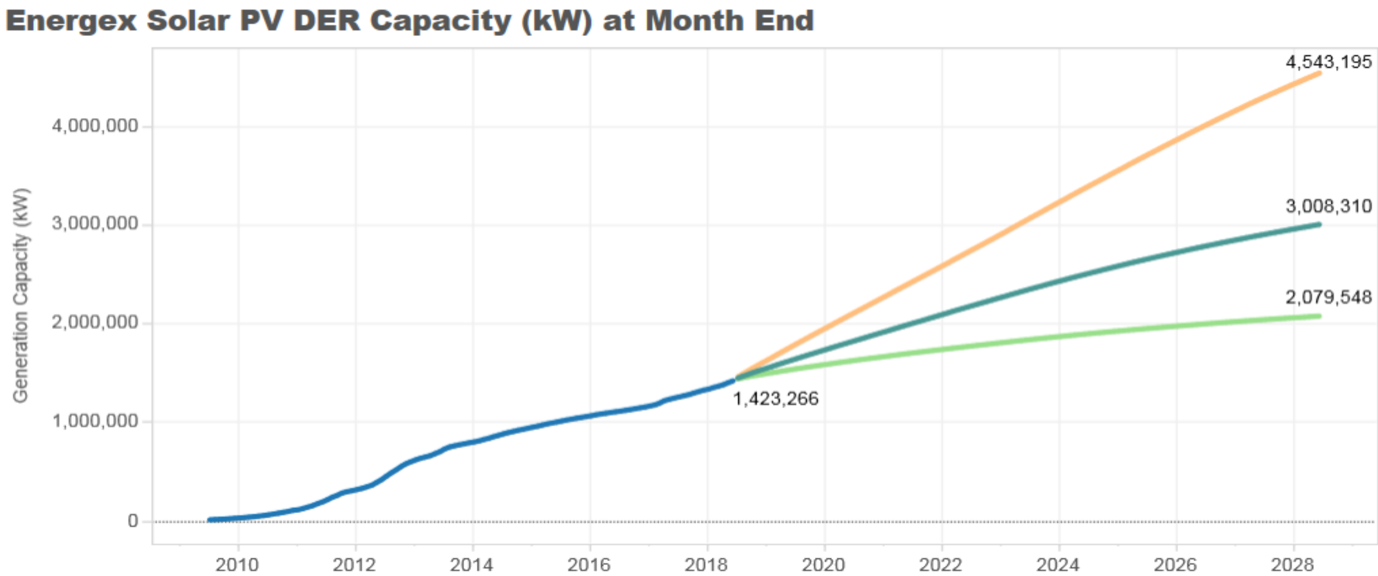

Figure 9: Projected Solar PV capacity growth to 2030

Current Solar PV Penetration

Energex currently has in excess of 50,000 distribution transformers with individual sizes ranging from 5kVA to 1500KVA in capacity. Table 24 shows the analysis of the Solar PV systems connected to these transformers by the percentage of distribution transformer rating. Approximately 60% of distribution transformers have Solar PV connected to them. Around 23% of the total population of the distribution transformers have PV penetration greater than 25% of the nameplate rating, which will result in reverse power flow back onto the HV during peak solar periods of the day.

Table 24: Solar PV penetration as a percentage of distribution transformer ratings

	% of Total Distribution Transformers				
PV capacity as % of distribution transformer rating	>75% of Rating	>50 <=75% of Rating	>25 <=50% of Rating	<25% of Rating	Without PV
Total Count: 50,512	0.6%	3.4%	19%	37%	40%

Table 25 shows the PV penetration data by feeder categories as a percentage of total distribution transformers with PV connection. Around 54% of the distribution transformers with PV connections are supplied from rural and approximately 44% from urban distribution feeders.

Table 25: Solar PV penetration by feeder category

	% of Total Distribution Transformers with PV connection			
Feeder Category	>75% of transformer Rating	>50 <=75% of transformer Rating	>25 <=50% of transformer Rating	<25% of transformer Rating
CBD	-	-	-	0.02%
Urban	-	4%	13%	27%
Rural	1%	2%	18%	33%

The impact of continued growth of Solar PV is expected to require network augmentation to ensure bidirectional power flow capabilities and statutory voltages. The current augmentation changes range from conductor changes and/or upgrades, transformer upgrades or replacement, regulator re-configuration changes and the installation equipment such as LV and HV line regulators in local areas where no other option is available.

Energex has begun trialling dynamic export limits for LV connected solar PV systems greater than 30kW as an alternative option to fixed partial or nil export limits. Based on real time measurements from the local transformer monitor, such as magnitude of reverse flow and voltage, PV systems with dynamic export limits can be ramped up and down, enabling additional customer generation, without limiting self-consumption or removing the option of zero-export limits at times when the network is constrained. This technology will soon also be demonstrated actively managing the rate of EV charging. Actively managed DER allows higher penetrations of DER to be connected without breaching network constraints. Real time PQ monitoring improves network visibility allowing closer operation to network limits, maximising DER operation.

High penetrations of PV cause unbalance on MV feeders and LV circuits as well as voltage rise. At the ends, customers increasingly suffer from curtailment associated with the Vnom-max setting. This setting only became available following the release of AS/NZS4777.2:2015 and became mandated by Energex’s connection standards from 30 September 2015. This was also when reactive power compensation requirements were introduced to help mitigate voltage rise. Inverters installed prior to this, which make up the majority of the connected population, were required to be compliant with the earlier AS4777.3:2005, which specifies a Vmax setting which can be as high as 270V despite Energex's requirements specifying 255V.

Currently, Energex specifies a value of 257V for Vnom-max which allows for up to 4V rise above 253V in customer premises. When inverters breach this limit for 10 minutes they disconnect. Where voltage rise between inverter and Point of Common Coupling (PCC) is less than 4V, the 257V limit allows voltages greater than 253V to be impressed on the network, requiring remediation. Reducing this value down to 255V, in line with AS/NZ4777.2, default for all new PV connections would reduce the likelihood of network overvoltage from new systems but would significantly increase curtailment of end customers and associated QoS enquiries.

Figure 10 outlines the number and type of QoS enquiries across the Energex network since 2014. Since 2013 the percentage of QoS enquiries (complaints) across the Energex networks for Solar PV related issues have ranged from 40 to 55% of all QoS enquires. Transition to the 230V standard contributed to a reduction in network voltages, reflected in a reduction in solar PV related enquiries in 2018 compared to 2017. However, the forecast increases in PV penetration are expected to cause a proportional rise in PV related QoS complaints.

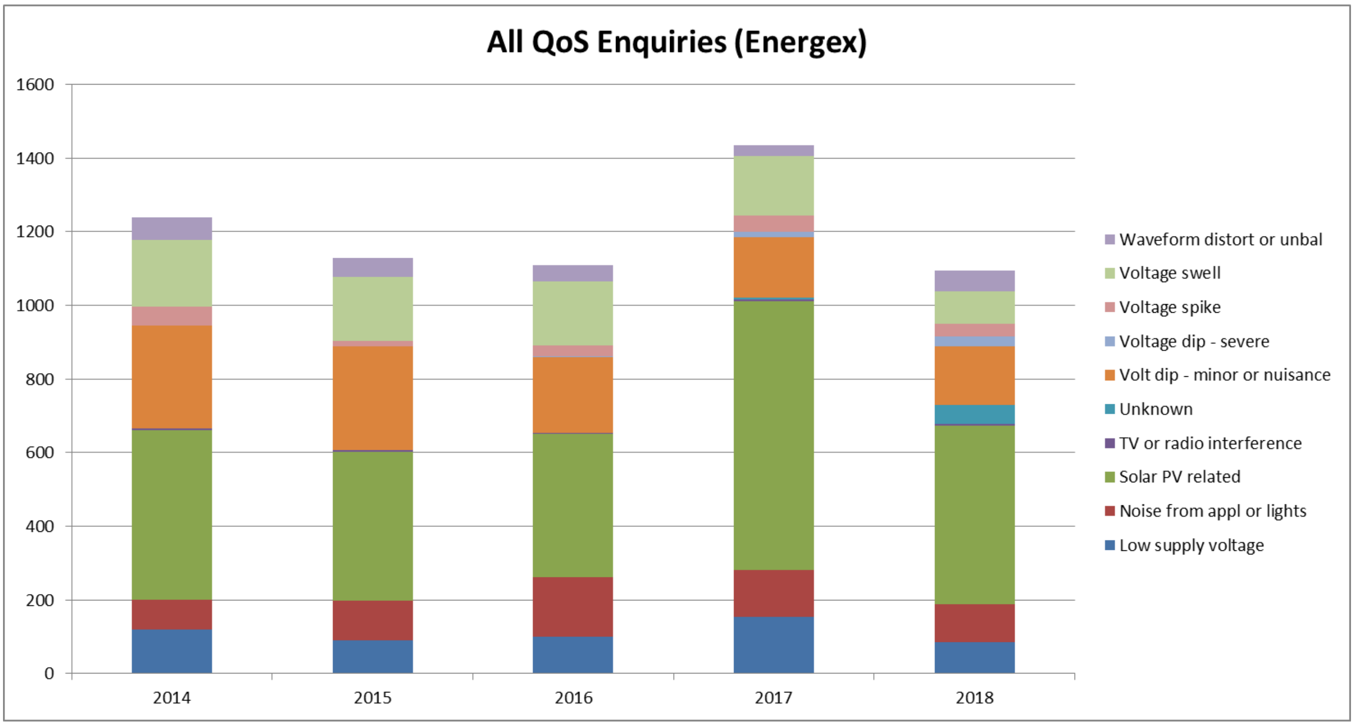

Figure 10: Number of all QoS enquiries at Energex by complaint types

Appendix H. Supporting Information on PQ Monitoring Program Design

The overall scope for distribution transformer monitoring program (CA15 & CA44 for overhead and underground networks respectively) to replace the existing Maximum Demand Indicators with power quality monitors sees a reduction of 31% of cost when compared to 2015-20 AER reset.

The CA48 program targets the installation of PQ monitors on distribution transformers where no monitoring devices were fitted previously, and the program specifically targets where all three phases require power quality monitoring.

The proposed estimate for CA15, CA44, and CA48 in 2020-25 is $13.3M, which is 54% of total actual spend in 2015/16-2018/19 and the estimated expenditure for the remaining of this regulatory period.

The CA29 program for monitoring of medium voltage (MV) networks is a new initiative. Both the causes and consequences of PQ problems can be diverse and they will not be addressed by a single or multiple solution(s) at the LV network or customer connection level. Network solutions implemented at MV level can target to resolve PQ issues experienced by multiple LV networks. Currently, the level of MV monitoring is not sufficient to develop solutions that can be implemented to resolve PQ issues potentially originating at 11kV network. Ad-hoc measurements are generally not suitable for this purpose as observation periods are limited and statistically weak, particularly given the daily and seasonal variation of loads and solar PV and the variations in network topology. There is no power quality or PV related augmentation program proposed specifically for Energex's MV networks. Hence CA29 is crucial for prudent and efficient investment planning to manage the PQ profile of MV networks, particularly as penetration levels and reverse flows continue to increase.

The volume of work for all of the PQ monitoring programs (CA15, CA44, CA29 and CA48) is primarily based on the level of PV penetration when compared to distribution transformer's rating (as detailed in Section 4.1 of our draft Strategic Proposal, Power Quality 2020-25). Since PV related QoS are predominant causes of customer complaints and higher PV penetrations are likely to cause broader network issues, it is prudent to target and monitor LV and MV networks with higher PV penetrations.

CA55 is required to keep the existing PQ monitors compatible with the new 4G communication network and will be replacing the remaining older versions (2G or 3G) of existing modems. The benefit is the network compatibility with the new technology and continuous functioning and remote visibility of existing PQ monitors. It is expected that 2G and 3G will not be operational from 2021/22. The proposed expenditure for CA55 is only 22% of actual spend between 2015/16 and 2018/19 and estimated budget for the remaining of this regulatory period.