Business Case

Substation Circuit Breakers and Reclosers Replacement Program

Executive Summary

Substation circuit breakers and reclosers switch load and fault currents in electrical networks using a range of electrical and mechanical operating mechanisms. In performing this function, they facilitate the safe and efficient operation of the network, protect plant and equipment from damage, and protect staff and the public from safety hazards that arise when faults occur in the electricity network.

Substation circuit breakers and reclosers are considered critical assets, given their important role in network protection. The lack of suitable alternatives for providing the same network protection services, coupled with the relatively long lead time associated with repairing or replacing a failed circuit breaker or recloser, means that their failure in-service is likely to result in safety consequences, as well as substantial and extended customer load interruption.

Two options for managing the risk of circuit breaker failure were evaluated for this business case:

Option 1 – Counterfactual, run-to-failure option, under which circuit breakers are permitted to fail in-service then replaced reactively.

Option 2 – Replacement is driven by a quantified risk assessment for each asset, which compares the cost of replacing the asset with the benefits realised by replacing the asset in terms of risk reduction.

Note that under both Option 1 and 2, reclosers are assumed to be replaced upon failure and replacement volumes are based on historical failure rates within the Ergon Energy network.

Ergon Energy 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 safety and reliability are strong drivers, based on the need to manage the risk of failure in-service of ageing and poor condition substation circuit breakers and reclosers.

Detailed quantitative risk assessments were carried out for each of the proposed circuit breaker replacements under Option 2 with reference to the counterfactual, 'run-to-failure' case presented under Option 1. The proposed circuit breaker replacements were based on asset condition, as per the Energy Queensland Asset Management Plan – Circuit Breakers and Reclosers.

The analysis indicated that for the proposed sites, the benefits realised in terms of risk reduction from replacing the assets before failure more than offset the cost of the replacement program outlined in Option 2. The Net Present Value (NPV) of Option 2 is $108M, indicating it delivers significant risk reduction benefits.

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
$45.6M	$0	$45.6M

Contents

1 Introduction

Ergon Energy undertakes the lifecycle management of substation circuit breakers and reclosers through performance and condition monitoring. Monitoring is carried out through periodic inspections, which are used to identify when asset maintenance, refurbishment or replacement is required. These actions are necessary to ensure that circuit breakers and reclosers are in a suitable condition to provide safe operational control for the network under both normal and fault conditions.

The Substation Circuit Breakers and Reclosers replacement program addresses the need to replace assets that are in poor condition and approaching the end of their useful life.

1.1 Purpose of document

This document recommends the optimal capital investment necessary for the Substation Circuit Breakers and Recloser replacement 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 Ergon Energy 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 (EQL) investment governance processes. The costs presented are in $2018/19 direct dollars.

1.2 Scope of document

The scope of this replacement program is restricted to circuit breakers and line-reclosers situated in substations within Ergon Energy's network.

This document should be considered in conjunction with the Energy Queensland (EQL) Asset Management Plan (AMP) – Circuit Breakers and Reclosers.

1.3 Identified Need

Ergon Energy 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 safety and reliability are strong drivers, based on the need to manage the risk of failure in-service of ageing and poor condition substation circuit breakers.

This program is a continuation of a previous replacement program for substation circuit breakers and line-reclosers in the Ergon Energy network.

Substation circuit breakers and reclosers are considered critical assets, given their important role in network protection. They are used in the network to open and close (i.e. switch) an electrical circuit under normal and fault conditions, providing safe operational control.

The lack of suitable alternatives for providing the same network protection services, coupled with the relatively long lead time associated with repairing or replacing a failed circuit breaker or recloser, means that their failure in-service is likely to result in safety consequences, as well as substantial and extended customer load interruption.

The relatively low population of circuit breakers makes it prudent and cost effective to manage them on an individual basis, proactively replacing them when they are approaching the end of their useful life and have fallen into poor condition. As such, the proposed circuit breaker replacements are for assets that are in poor condition and approaching the end of their service life. This is in alignment with the EQL AMP – Circuit Breakers and Reclosers.

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 replacement of Circuit Breakers and Reclosers 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: Asset Function and Strategic Alignment

Objectives	Relationship of Initiative to Objectives
Ensure network safety for staff contractors and the community	Circuit breaker or recloser failure can result in very significant risks for staff and the public, hence a suitable remediation program for assets in poor condition is critical.
Meet customer and stakeholder expectations	The reliable performance of circuit breakers and reclosers supports and promotes delivery of a standard quality electrical energy service. Proper functioning of these assets ensures that outages are not unnecessarily extended, and that maintenance is not prevented by constrained access to substation sites.
Manage risk, performance standards and asset investments to deliver balanced commercial outcomes	Failure of circuit breakers or reclosers can result in increased EQL personnel and public safety risks and disruption of the electricity network. Individual circuit breaker failure can cascade into a major catastrophic failure of the substation switchgear. Asset longevity assists in minimising capital and operational expenditure.
Develop Asset Management capability & align practices to the global standard (ISO55000)	This approach is consistent with ISO 55000 objectives and drives asset management capability by promoting a continuous improvement environment.
Modernise the network and facilitate access to innovative energy technologies	This proposal promotes modernisation through industry leading condition and health assessment, replacement of circuit breakers and reclosers at end of economic life as necessary to suit modern standards and requirements.

1.5 Applicable service levels

Corporate performance outcomes for this asset 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: Compliance obligations related to this replacement program

Legislation, Regulation, Code or Licence Condition	Obligations	Relevance to this investment
QLD Electrical Safety Act 2002 **QLD Electrical Safety Regulation 2013**	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: • 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]	This replacement program addresses the need to replace substation circuit breakers and reclosers in the network which are in poor condition and therefore at greater risk of failure. When these assets fail, they pose a safety risk for staff, the public and other assets in the network both directly through explosive failure and indirectly by not providing automatic protection from network faults and preventing operators from isolating portions of the network when works must be carried out.
Distribution Authority for Ergon Energy 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 replacement program is necessary to meet safety net targets and MSS, by ensuring the reliable operation of the network under both normal and fault conditions. The automatic opening or closing of circuit breakers and reclosers is required to provide protection to substation equipment.
National Electricity Rules, 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	Substation circuit breakers and reclosers are a critical part of the protection system for the network, providing automatic protection under fault conditions. This replacement program is

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

Legislation, Regulation, Code or Licence Condition	Obligations	Relevance to this investment
	• Section S5.1a.8 Fault Clearance Times • Section S5.1.2 Credible Contingency Events	therefore required to ensure they remain in a suitable condition, and the National Electricity Rules are not breached.

1.7 Limitation of existing assets

The replacement of substation circuit breakers and reclosers is required due to the degradation of these assets over the course of their service life. There are several factors that affect the condition of these assets and ultimately drive the need for replacement.

Electrical and mechanical wear, incurred during regular operation over the course of asset service life, leads to a general decline in the reliability of its operation over time. This kind of wear is typically directly related to asset age, but cumulative operations to interrupt short circuits and load current will also increase the electrical and mechanical wear experienced by the circuit breaker or recloser and reduce its useful life at a faster than normal rate.

Environmental factors also accelerate the ageing process and lead to the non-operation of circuit breaker or recloser mechanisms. Circuit breakers or reclosers situated in outdoor, corrosive and coastal environments will experience accelerated degradation of components such as their bushing insulators, tank and gaskets.

Asset obsolescence can also drive the need for replacement. For older circuit breaker and recloser designs, the manufacturers no longer supply replacement units or spare parts. As a result, it is not possible to return these units to service in the event of failure.

Finally, some additional performance issues have been identified for specific circuit breaker models that are deployed in Ergon Energy's network and which will require replacement to address. These are outlined in the remainder of this section.

Oil Filled Circuit Breakers Without Remote Control

Manually operated oil filled circuit breakers installed in an indoor environment inside a substation building pose a serious safety hazard compared to remote controlled oil-filled circuit breakers as the operator is standing next to the circuit breaker during switching. These assets are not designed to enclose or direct the blast associated with a fault away from the operator which can result in serious safety consequences.

The Ergon Energy network has six non-remote-controlled oil filled circuit breakers across two substations and these are programmed to be replaced with modern fit-for-purpose equivalent units within the 2020-2025 regulatory period.

Indoor Breakers in Outdoor Cubicles

Three catastrophic in-service failures of Email manufactured S15 circuit breakers were recently experience in one year in the Energex network, the other distribution network within Queensland. An investigation found the failure was due to indoor circuit breakers incorrectly being installed in outdoor cubicles. These circuit breakers were not designed for the additional exposure to the elements, which led to the deterioration of their insulation and ultimately failure. Failure of the high-voltage (HV) insulation can present a safety risk to any personnel in the substation, as it can lead to the explosion of the porcelain bushings. Regular partial discharge (PD) scanning is used to monitor the immediate risk of this occurring.

In the Ergon Energy network, seven S15 11kV indoor circuit breakers were installed in outdoor cubicles in one substation in the year 1970. While the same catastrophic in-service failures have not yet been observed by Ergon Energy, the continued operation of assets designed for indoor use in outdoor conditions poses a significant risk to staff working in substations. These circuit breakers are planned to be replaced by modern fit-for-purpose equivalent assets by 2022.

Other Discovered Deficiencies

Several circuit breaker models that have deficiencies have been discovered during their in-service life and have been the subject of detailed investigation. Table 3 summarises the identified circuit breakers have been programmed to be replaced with modern fit-for-purpose equivalents over coming years (determination periods 2015-2020 and 2020-2025).

Table 3: Identified Circuit Breaker Deficiencies

Circuit Breaker Model	Identified Deficiency
ASEA – HLC	These circuit breakers have a history of explosive failure due to moisture ingress. In addition, several similar (much older) ASEA HKEY Circuit Breakers are included for replacement due to similar issues.
Delle HPGE	These breakers have a history of slow operation which has led to the operation of backup protection systems and extensive outages. The '3 mechanism' model (which experiences the slow operating issue as well as timing discrepancies between the three separate poles) is prioritised slightly higher than the single mechanism model.
GEC – FL1	These breakers have a history leaking sulphur hexafluoride (SF6), slow operation, failing to latch and moisture ingress. Only one of these circuit breakers remains in the network.
ABB – VBF	These breakers have a history of moisture ingress from loss of gas pressure. This has caused catastrophic failures when the circuit breaker operates.
EIB and Sprecher & Shuh – HPFA	These breakers have an issue where the arc interrupting turbulator falls off inside the circuit breaker, and there is a risk that this will lead to catastrophic failures when the circuit breaker operates.

2 Counterfactual Analysis

Under a ‘run-to-failure’ counterfactual approach, substation circuit breakers and reclosers would be permitted to fail in-service, rather than being replaced based on condition, age and risk factors. The key issue associated with this approach is that it would decrease the availability of network protection services, leading to negative safety and reliability outcomes.

2.1 Purpose of asset

Substation circuit breakers and reclosers switch load and fault currents in electrical networks using a range of electrical and mechanical operating mechanisms. In performing this function, they facilitate the safe and efficient operation of the network, protect plant and equipment from damage, and protect staff and the public from safety hazards that arise when faults occur in the electricity network.

2.2 Business-as-usual service costs

Ergon Energy has 5,431 circuit breakers and reclosers in service throughout its network. Condition is the key driver for replacement of these assets.

Substation circuit breaker and recloser condition and failure consequence risks (safety, customer reliability, environmental and business) are regularly assessed for each individual asset. The worse the condition of the asset, the higher the likelihood of its in-service failure.

These assets are currently replaced on a proactive basis, with the aim of limiting the amount of in-service failures that occur (along with the associated safety consequences and interruptions to customer load).

2.3 Key assumptions

Failure to maintain substation circuit breakers and reclosers can result in the loss of services that are required to safely operate the network. Under a ‘run-to-failure’ counterfactual approach, the increased failure of circuit breakers would prevent the safe and efficient operation of the network. Appendix F details the input assumptions associated with the quantification of risk of the condition-related failure for the set of Ergon Energy substation circuit breakers considered in this business cases.

Qualitatively, the failure in-service of substation circuit breakers has several potential consequences:

- **Catastrophic failure of an asset:** Failure events have the potential to result in safety consequences such as damage to other substation equipment, harm to staff or harm the public.
- **Extended interruption of customer load**: Due to the critical nature of circuit breakers and reclosers in the network, and the extended lead time required to procure circuit breakers in particular, their failure can lead to lengthy disruptions to supply for customers.
- **Loss of access to substation sites:** When circuit breakers or reclosers have been identified as being in sufficiently poor condition, a Network Access Restriction (NAR) is imposed on the substation for safety reasons. This restricts both site access and the scope of operations that can be performed on site, adding cost to routine works and inhibiting network operation.

A ‘run-to-failure’ approach also ignores the risk posed by known failure modes in specific circuit breaker models, particularly with respect to known causes of catastrophic failure. It is therefore an imprudent approach to asset management for this asset class.

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 4: Counterfactual risk assessment

Risk Scenario	Risk Type	Consequence (C)	Likelihood (L)	Risk Score	Risk Year
Loss of Control – In-service failure of a circuit breaker or reclosers in a substation, leading to an **abnormal network configuration**.	Business Impact	3 *(Inability to remotely control a substation, or abnormal network configuration)*	4 *(Likely)*	**12** ***(Moderate Risk)***	2025
Catastrophic failure – **A serious injury** occurs when a circuit breaker or recloser fails in-service in a catastrophic manner with a member of staff or the public near the asset.	Safety	4 *(Multiple Serious Injuries)*	3 *(Unlikely)*	**12** ***(Moderate Risk)***	2025
Protection – In-service failure of a circuit breaker or recloser in a substation leaving the network with inadequate protection, leading to a **breach of the National Electricity Rules**.	Legislated	4 *(Improvement notice issued by the regulator)*	4 *(Likely)*	**16** ***(Moderate Risk)***	2025
Interruption of customer load – Failure of a substation circuit-breaker while in-service leads to an interruption of customer load, as individual circuit breaker failure can cascade into a **major catastrophic failure of the substation switchgear**.	Customer	4 *(Disruption to multiple large-scale business or essential services)*	4 *(Likely)*	**16** ***(Moderate Risk)***	2025

2.5 Retirement or de-rating decision

Substation circuit breakers and reclosers perform a critical role supplying network protection services. Without them, the safe and efficient operation of the network cannot be supported under either normal or fault conditions. There is no alternative asset which can perform the same function, so they cannot be considered for retirement.

3 Options Analysis

This section outlines the options considered to manage the replacement of substation circuit breakers and reclosers within the Ergon Energy network.

3.1 Options considered but rejected

None of the identified options for this business case have been rejected without further analysis.

3.2 Identified options

Two network options have been developed to manage the replacement of substation circuit breakers. These are:

- Option 1 – 'Run-to-Failure' (Counterfactual)
- Option 2 – Risk Based Replacement (Recommended)

3.2.1 Network options

Option 1 – 'Run-to-Failure' (Counterfactual)

Under the option, substation circuit breaker and reclosers are only replaced reactively once they fail in-service. See Section 2 for details.

Option 2 – Risk Based Replacement (Recommended)

Under this option, substation circuit breaker condition is to be monitored on an individual asset basis. Replacement is driven by a quantified risk assessment for each asset, which compares the cost of replacing the asset with the benefits realised by replacing the asset in terms of risk reduction.

Once the benefits are found to outweigh the cost of replacement, the circuit breaker becomes a candidate for replacement. Where possible, asset replacement is aligned with other works in the same substation to limit disruption to the network.

Line-reclosers are assumed to be replaced on failure, with an annual failure rate of 38 units assumed based on historical failure rates in the Ergon Energy network.

This approach results in the replacement of 108 substation circuit breakers and 190 line-reclosers over the 2020-25 regulatory period.

3.2.2 Non-network options

There was no non-network option identified for this business case. Substation circuit breakers provide critical network protection services, and there is no alternative asset or method for providing these services that would facilitate a non-network option.

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 FY2019/20 to FY2049/50, using EQL's standard NPV analysis tool. The Regulated Real Pre-Tax Weighted Average Cost of Capital (WACC) rate of 2.62% has been applied as the discount rate for this analysis (as per EQL's Standard NPV Tool).

Risk Monetisation

The risk of asset failure has been assessed along with the potential consequences of failure for both Option 1 and Option 2, to produce a monetised total risk value for each year across the period for both options.

Benefits of Replacement

The benefit of replacement for each individual asset has been calculated by comparing the total quantified risk in dollar terms for leaving the asset in place (as per Option 1) with the total quantified risk if the asset is replaced (as per Option 2). The reduction in risk achieved by implementing Option 2 relative to Option 1 is the benefit of that option.

Cost of Replacement

The average all in cost of substation circuit breaker replacement was assumed to be $387,000, which is based on past replacement cost data for Ergon Energy's network. Similarly, the average cost for line reclosers was assumed to be $20,000.

Results

The result of NPV of implementing the recommended option (Option 2) at each of the proposed substation sites is summarised below in Table 5. The replacement at each site is justified relative to the counterfactual option (Option 1), as the risk reduction realised at each site outweighs the cost of replacing the circuit breakers.

Table 5: Net present value results by substation site

Substation Site	PV CAPEX ($M)	PV Benefits ($M)	NPV ($M)
Awoonga	$1,469,965	$5,719,290	$4,249,326
Biloela	$2,380,395	$13,577,169	$11,196,774
Boyne	$367,491	$1,008,808	$641,317
Calen	$680,113	$3,290,891	$2,610,779
Cape River	$1,432,435	$1,888,638	$456,203
Chinchilla Town	$367,491	$2,733,196	$2,365,704
East Bundaberg	$716,218	$2,940,764	$2,224,547
Frenchville	$754,239	$2,218,558	$1,464,319
Garbutt	$367,491	$1,008,808	$641,317
Howard	$2,204,947	$10,287,932	$8,082,985
Jandowae	$734,982	$5,527,192	$4,792,209
Kilkivan Town	$1,020,169	$5,267,867	$4,247,698
Lakes Creek	$754,239	$2,273,350	$1,519,111
Maryborough	$3,140,693	$8,922,139	$5,781,447

Substation Site	PV CAPEX ($M)	PV Benefits ($M)	NPV ($M)
Meringandan	$697,932	$4,180,936	$3,483,004
Mossman	$1,102,474	$198,298	-$904,176
Murgon	$1,020,169	$3,001,407	$1,981,238
Owanyilla	$348,966	$738,214	$389,248
Pialba	$2,380,395	$11,996,559	$9,616,164
Sarina	$2,040,338	$5,499,127	$3,458,789
Tennyson Street	$7,542,389	$23,004,457	$15,462,068
Turkinje	$2,506,761	$9,740,432	$7,233,671
Victoria	$1,395,863	$7,406,795	$6,010,932
West Toowoomba	$3,060,507	$14,061,701	$11,001,194
Total	**$38,486,662**	**$146,492,528**	**$108,005,866**

It is noted that one site (Mossman) provides a negative NPV based on the risk quantification conducted. While this individual result is negative, the overall program is positive and supported by the risk quantification analysis.

3.4 Scenario Analysis

3.4.1 Sensitivities

Two of the key drivers of the quantitative risk assessment have been flexed for a marginal NPV site (Cape River) and a high CAPEX site (Tennyson Street) to test the suitability of the proposed options. The inputs flexed were:

- **Asset characteristic life**: This value drives the Weibull distribution which was used to assess the likelihood of asset failure. In general, a higher characteristic life will result in a lower likelihood of failure for the asset.
- **Fatality probability of severity (PoS):** A significant component of the risk attached to a circuit breaker failure is associated with the cost of a fatality.

The impact of flexing these two inputs on the NPV for each site are summarised in Table 6.

Table 6: Sensitivity analysis on key inputs for select sites (NPV $ 000s)

Substation	Base NPV	Characteristic Life		Fatality PoS	
		-5 years	+5 years	-5%	+5%
Cape River	456	1,012	50	-57	970
Tennyson Street	15,462	22,773	10,228	10,399	20,525

Cape River, the more marginal case, has a slightly negative NPV result when the probability of severity for a fatality is reduced by 5%.

3.4.2 Value of regret analysis

In terms of selecting a decision pathway of 'least regret', Option 2 presents an economically efficient balanced approach to investment by targeting replacement works based on assessed condition and reducing risk to the greatest extent without bringing forward unnecessary expenditure.

The key regret identified in this business case is the potential loss of network protection services, leading to negative safety outcomes (e.g. a fatality or serious injury) and customer load interruption.

The economic value of this risk has been quantified as part of the analysis, with Option 2 delivering a $146.5 million benefit in terms of reduced total risk (as compared to Option 1). Option 2 therefore produces the lower risk cost in relation to total risk.

3.5 Qualitative comparison of identified options

3.5.1 Advantages and disadvantages of each option

Table 7 details the advantages and disadvantages of each option considered.

Table 7: Qualitative Assessment of Options

Options	Advantages	Disadvantages
Option 1 – 'Run-to-Failure' (Counterfactual)	• Makes complete use of asset useful life for circuit breakers	• Increases the rate of in-service failure, reducing access to network protection services and driving negative safety consequences • High likelihood of network access restrictions being applied, reducing the ability to perform maintenance tasks and increasing the likelihood of outages being required to perform work
Option 2 – Risk Based Replacement (Recommended)	• Reduced risk to staff and the community • Enables consideration of asset consolidation	• Potentially higher cost than Option 1, as assets will be replaced slightly before the end of their useful life.

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 of work does not contribute directly to Energy Queensland's transition to an Intelligent Grid, in line with the Future Grid Roadmap and Intelligent Grid Technology Plan. However, it does support Energy Queensland in maintaining affordability of the distribution network while also maintaining safety, security and reliability of the energy system, a key goal of the Roadmap, and represents prudent asset management and investment decision-making to support optimal customer outcomes and value across short, medium and long-term horizons.

3.5.4 Risk Assessment Following Implementation of Proposed Option

Table 8 outlines the risk assessment for the Ergon Energy network following the implementation of the preferred option (Option 1).

Table 8: Risk assessment showing risks mitigated following Implementation

Risk Scenario	Risk Type	Consequence (C)	Likelihood (L)	Risk Score	Risk Year
<u>Loss of Control</u> – In-service failure of a circuit breaker or recloser in a substation, leading to an **abnormal network configuration**.	Business Impact	*(Original)* 3 (Mitigated) 3 *(Inability to remotely control a substation, abnormal network configuration)*	4 *(Likely)* 3 *(Unlikely)*	**12** ***(Moderate Risk)*** **9** ***(Low Risk)***	2025
<u>Catastrophic failure</u> – **A serious injury** occurs when a circuit breaker or recloser fails in-service in a catastrophic manner with a member of staff or the public near the asset.	Safety	*(Original)* *4* (Mitigated) 4 *(Multiple Serious Injuries))*	*3* *(Very Unlikely)* 2 *(Very Unlikely)*	***12*** ***(Moderate Risk)*** **10** ***(Low Risk)***	2025
<u>Protection</u> – In-service failure of a circuit breaker or recloser in a substation leaving the network with inadequate protection, leading to a **breach of the National Electricity Rules**.	Legislated	*(Original)* *4* (Mitigated) 4 *(Improvement notice issued by the regulator)*	*4* *(Likely)* 3 *(Unlikely)*	***16*** ***(Moderate Risk)*** **12** ***(Moderate Risk)***	2025
<u>Interruption of customer load</u> – Failure of a substation circuit-breaker while in-service leads to an interruption of customer load, as individual circuit breaker failure can cascade into a **major catastrophic failure of the substation switchgear**.	Customer	*(Original)* *4* (Mitigated) 4 *(Disruption to multiple large-scale business or essential services)*	*4* *(Likely)* 3 *(Unlikely)*	***16*** ***(Moderate Risk)*** **12** ***(Moderate Risk)***	2025

4 Recommendation

4.1 Preferred option

The preferred option for this business case is Option 2 – Risk Based Replacement. Under this option, substation circuit breakers and reclosers are considered for replacement once the benefits that result from their replacement outweigh the costs of doing so (assessed via a quantitative risk assessment process).

4.2 Scope of preferred option

The replacement schedule and associated CAPEX (in real 2018/19 dollars) across the 2020-25 regulatory period is outlined in Table 9 for circuit breakers and Table 10 for line-reclosers. The total program expenditure over the regulatory period is $45.6 million (in real 2018/19 dollars), with 108 circuit breakers and 190 line-reclosers to be replaced over the period.

Table 9: Planned replacement volume and expenditure – circuit breakers

	2020-21	2021-22	2022-23	2023-24	2024-25	Total
Circuit Breakers	24	20	11	14	37	108
CAPEX ($ 000s)	3,719	3,099	1,705	2,169	5,734	$41,800

Table 10: Planned replacement volume and expenditure – line reclosers

	2020-21	2021-22	2022-23	2023-24	2024-25	Total
Reclosers	38	38	38	38	38	190
CAPEX ($ 000s)	760	760	760	760	760	$3,800

The expenditure information in this business case is represented in the same manner as the Reset RIN Repex template. For example, if a project/program contains multiple assets (e.g.: OH conductor, poles & pole top structures), the total expenditure is apportioned to respective RIN assets individually as per the Ergon Energy RIN expenditure allocation methodology.

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).*

AEMO, *Value of Customer Reliability Review, Final Report,* (September 2014).

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

Energy Queensland, *Asset Management Plan, Circuit Breakers and Reclosers [7.028]*, (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, *Network Risk Framework*, (October 2018).

Ergon Energy, *Distribution Annual Planning Report (2018-19 to 2022-23) [7.049]*, (21 December 2018).

Appendix B. Acronyms and Abbreviations

The following abbreviations and acronyms appear in this business case.

Abbreviation or acronym	Definition
$M	Millions of dollars
$ nominal	These are nominal dollars of the day
$ real 2019-20	These are dollar terms as at 30 June 2020
2020-25 regulatory control period	The regulatory control period commencing 1 July 2020 and ending 30 Jun 2025
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
ALARP	As Low as Reasonably Practicable
AMP	Asset Management Plan
Augex	Augmentation Capital Expenditure
BAU	Business as Usual
CAPEX	Capital expenditure
CB	Circuit Breaker
Current regulatory control period or current period	Regulatory control period 1 July 2015 to 30 June 2020
DAPR	Distribution Annual Planning Report
DC	Direct Current
DNSP	Distribution Network Service Provider
EQL	Energy Queensland Ltd
HI	Health Index
HV	High Voltage
IT	Information Technology
KRA	Key Result Areas
kV	Kilovolt
LV	Low Voltage
MSS	Minimum Service Standard
MVA	Megavolt Ampere
NEL	National Electricity Law
NEM	National Electricity Market
NEO	National Electricity Objective
NER	National Electricity Rules (or Rules)

Abbreviation or acronym	Definition
Next regulatory control period or forecast period	The regulatory control period commencing 1 July 2020 and ending 30 Jun 2025
NPV	Net Present Value
OPEX	Operational Expenditure
PCBU	Person in Control of a Business or Undertaking
PD	Partial Discharge
Previous regulatory control period or previous period	Regulatory control period 1 July 2010 to 30 June 2015
PV	Present Value
Repex	Replacement Capital Expenditure
RIN	Regulatory Information Notice
RIT-D	Regulatory Investment Test – Distribution
RTS	Return to Service
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SAMP	Strategic Asset Management Plan
SCADA	Supervisory Control and Data Acquisition
SF6	Sulphur Hexafluoride
SFAIRP	So Far as Is Reasonably Practicable
WACC	Weighted average cost of capital
ZS	Zone Substation

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 11: 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	This program is required to manage safety risks in accordance with the Electrical Safety Act and associated Regulations.
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	The failure of these assets is likely to impact reliability; hence this proposal addresses the reliability of supply.
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 program is required to manage safety risks in accordance with the Electrical Safety Act and associated Regulations.
6.5.7 (c) (1) (i) The forecast capital expenditure reasonably reflects the **efficient costs** of achieving the capital expenditure objectives	The Unit Cost Methodology and Estimation Approach sets out how the estimation system is used to develop project and program estimates based on specific material, labour and contract resources required to deliver a scope of work. The consistent use of the estimation system is essential in producing an efficient CAPEX forecast by enabling: • Option analysis to determine preferred solutions to network constraints • Strategic forecasting of material, labour and contract resources to ensure deliverability • Effective management of project costs throughout the program and project lifecycle, and • Effective performance monitoring to ensure the program of work is being delivered effectively. 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 and the quantification of risk and benefits of each option. 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 12: 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	**SFAIRP** Risks in this area to be mitigated So Far as is Reasonably Practicable
18 – 23	***High Risk***		**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***		**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**				
1 to 5	***Very Low Risk***		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*	

Figure 1: A Risk Tolerability Scale for evaluating Semi-Quantitative risk score

Appendix F. Quantitative Risk Assessment Details

Data Input			
		Description/Justification	**Source**
Asset Class	Circuit Breakers (CBs)	-	-
NPV Period (years)	30	-	-
Unit Rate ($)	387,000	Average forecasted expenditure within the 2020-2025 regulatory period.	Attachment 7.058 of our initial regulatory proposal.
Emergency Replacement Unit Rate ($)	503,100	Based on the added costs involved with replacements when responding to a failure in-service event.	Assumed based on EQL and peer organisation industry experience.

Customer Risk Inputs			
		Description/Justification	**Source**
Percentage of Mix	-	Site specific percentage figure based on substation scheme	Input data provided by EQ
CB Consequence Monetisation ($)	-	Site specific dollar figure calculated from a CB failure in an Urban/Rural location, and whether the failure was catastrophic or functional	-

CB Failure Risk Inputs					
Location	**Failure Type**	**Consequence Monetisation**	**Disp. Factor**	**Description/Justification**	**Source**
Urban	**Catastrophic**	1,145,965	1	Based on average costs observed in Ergon Energy's network. These are applied based on whether the substation is in an urban or rural area, and whether the asset fails in a catastrophic or functional manner. Based on estimates for the Ergon Energy network, 13% of circuit breaker failures are catastrophic and 87% are functional failures.	As agreed with EQ.
	Functional	687,579	1		
Rural	**Catastrophic**	363,166	1		
	Functional	201,759	1		

Reliability Model			
		Description/Justification	**Source**
Shape parameter (β)	4	-	Based on industry peer's information
Characteristic life (η)	75/80	Depends on whether CBs are 11kV or > 11kV	Based on industry peer's information
CB Age at 2020	-	Current age of existing Circuit Breaker/s. In the case of multiple CBs with unique ages, the average is used throughout.	Input data provided by EQ
Replacement Year from 2020	-	Year at which the replacement CB/s will be installed	Input data provided by EQ

Incident Conversion Rate (ICR) & Probability of Consequence (PoC)						
ICR		PoC				
Consequence	**Incidents Attr. to Cons.**	**Category**	**Risk Scale**	**Probability of Severity**	**Description/Justification**	**Source**
Single Fatality	1	Safety	5	1.00%	ICR - 20% of incidents are attributed to a single fatality. Estimated based on frequency of staff maintenance and accessibility to general public. PoC – 1% of incidents result in a single fatality. Based on the severity of the consequence being considered as major.	ICR - Assumed based on EQL and peer organisation industry experience. PoC - Assumed based on EQL and peer organisation industry experience.
Major Injury	2.5	Safety	4	4.00%	ICR - 50% of incidents are attributed to a major injury. Estimated based on frequency of staff maintenance and accessibility to general public. PoC - 4% of incidents result in a major injury. Based on the severity of the consequence being considered as moderate to major.	ICR - Assumed based on EQL and peer organisation industry experience. PoC - A Assumed based on EQL and peer organisation industry experience.
Fire	1	Fire	3	10%	ICR - 20% of incidents are attributed to a fire. Calibrated based on the expected costs involved with fire risks relative to costs involved with safety, and oil hazards involved with the asset. PoC - 10% of incidents result in a fire. Based on the severity of the consequence being considered as minor to moderate.	ICR - Assumed based on EQL and peer organisation industry experience. PoC - Assumed based on EQL and peer organisation industry experience.
Customer Outage	5	Safety	4	4.00%	ICR - 100% of incidents are attributed to customer outages. Assuming circuit breaker functional failures result in an outage only where there is no redundancy. Assuming circuit breaker catastrophic failures result in an outage. PoC - 100% of incidents result in a customer outage	ICR - Assumed based on EQL and peer organisation industry experience. PoC - Assumed based on EQL and peer organisation industry experience.
Environment	0.5	Fire	2	10.00%	ICR - 10% of incidents are attributed to an environmental issue. PoC - 10% of incidents result in an environmental issue.	ICR - Assumed based on EQL and peer organisation industry experience.

Incident Conversion Rate (ICR) & Probability of Consequence (PoC)						
					Based on the severity of the consequence being considered as minor to moderate.	PoC - Assumed based on EQL and peer organisation industry experience.
Emergency Response	5	Fire	2	100%	ICR - 100% of incidents are attributed to an emergency response PoC - 100% of incidents result in an emergency response	ICR - Assumed based on EQL and peer organisation industry experience. PoC - Assumed based on EQL and peer organisation industry experience.
Total No. of Incidents	**5**	-	-	-	Based on known CB failures in the 16/17 financial year period.	Attachment 7.028 of our initial regulatory proposal.

Safety Risk Inputs				
Consequence	**Monetisation ($)**	**Disproportionality Factor**	**Description/Justification**	**Source**
Single Fatality	4,900,000	10	Cost of a single fatality scaled by factor of 10.	[1] The sources used to develop the Disproportionality Factors are as follows: Ausgrid - Revised Proposal - Attachment 5.13.M.4 - Low Voltage Overhead Service Lines program CBA summary - January 2019 https://www.pmc.gov.au/sites/default/files/publications/value-of-statistical-life-guidance-note_0_0.pdf https://www.hse.gov.uk/risk/theory/alarpcba.htm
Single Series Injury	490,000	8	Cost of a single serious injury scaled by a factor of 8.	
Fire	66,000	4	Cost of a fire scaled by a factor of 4.	

[1] Disproportionality factors are applied to the consequence monetisation to offset the gross disproportion (perceived point at which the cost of implementing a safety measure exceeds its expected benefits). The above factors are based on a review of peer organisations, as well as other industries, to identify a single factor within the approximate median of the range of factors identified in the review.

Appendix G. Reconciliation Table

Reconciliation Table Conversion from $18/19 to $2020	
Business Case Value (M$18/19)	$45.60
Business Case Value (M$2020)	$47.59