Instrument Transformer Replacements

Business Case

25 January 2024

Part of Energy Queensland

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DOCUMENT VERSION

Version Number	Change Detail	Date	Updated by
Draft v0.1	Initial Draft	16/03/2023	Asset Strategy Engineer
Draft v0.2	AER Document Initial Release	31/05/2023	Asset Strategy Engineer
Draft v0.3	Finalised Draft – Formatted	09/11/2023	Manager Asset Strategy
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RELATED DOCUMENTS

Document Date	Document Name	Document Type
JAN 2024	Asset Management Plan – Instrument Transformers	PDF
NOV 2023	Instrument Transformer CBRM/CNAIM Model Rcode	Excel
28/07/2023	Network Risk Framework ID2877290	PDF
17/06/2022	Electrical Safety Regulation 2013 (QLD)	PDF
V3	Substation Defect Classification Manual - Instrument Transformers	PDF
01/06/2023	RIN 2.2 Compare 2021-22 (Rosetta)	Excel
NOV 2023	Energex 2022-23 - Category Analysis - RIN Response - Consolidated - 24 November 2023 – PUBLIC (16063386.1)	Excel
OCT 2023	Lines Defect Classification Manual	PDF
V3	Substation Defect Classification Manual	PDF
JUN 2023	Maintenance Acceptance Criteria (MAC) – Release 11	PDF
AUG 2023	Maintenance Activity Frequency (MAF) – Release 2	PDF

1 SUMMARY

<table>
<tr><th>Title</th><th>EGX Instrument Transformers Business Case AER 2025-30</th></tr>
<tr><td>DNSP</td><td>Energy Queensland (EQL) – Energex Ltd</td></tr>
<tr><td>Expenditure category</td><td>☒ Replacement ☐ Augmentation ☐ Connections ☐ Tools and Equipment ☐ ICT ☐ Property ☐ Fleet</td></tr>
<tr><td>Identified need</td><td>☒ Legislation ☒ Regulatory compliance ☒ Reliability ☐ CECV ☒ Safety ☒ Environment ☒ Financial ☐ Other

The objective of this Business Case document is to outline the limitation forecast associated with instrument transformers in accordance with the lifecycle management strategies detailed in the Asset Management Plan (AMP). Additionally, this Business Case provides the necessity for interventions, both in terms of volume and financial allocations during the regulatory period 2025-30, as informed by the results of CNAIM/CBRM modelling.

Instrument Transformers play a critical role in the protection, measurement, and control of Energex's network, and failures or outages of instrument transformers can significantly degrade or prevent access to these important functions.</td></tr>
<tr><td>Expenditure</td><td>The expenditure presented in this business case relates to the replacement of instrument transformers which are largely undertaken in combination with a range of asset replacements within a substation.

<table>
<tr><th>Year</th><th>2025/26</th><th>2026/27</th><th>2027/28</th><th>2028/29</th><th>2029/30</th><th>Total</th></tr>
<tr><td>$m, direct 2022-23</td><td>1.1</td><td>1.5</td><td>0.7</td><td>0.9</td><td>0.7</td><td>4.9</td></tr>
<tr><td>Quantity</td><td>1</td><td>0</td><td>46</td><td>0</td><td>41</td><td>88</td></tr>
</table>
</td></tr>
<tr><td>Optimal timing and NPV analysis</td><td>Within the framework of the Network Planning Process, an assessment is conducted for the limitations associated with each instrument transformer. Subsequently, individual projects are initiated, and an assessment undertaken to determine the optimal timing for their replacement. This procedure involves performing Net Present Value (NPV) analysis, risk assessment, and consolidating activities with other network assets in suboptimal condition at a designated timing. We ensure prudency and efficiency, ultimately curbing the financial impact on our customers and the broader community.

Attachment 5.2.01 SCS Capex model – January 2024 outlines our overall investments for the 2025-2030 period, which will include instrument transformers. Business cases for those investments are available on request.</td></tr>
</table>

2 PURPOSE AND SCOPE

The objective of this business case document is to define the projected limitations related to Circuit breakers and reclosers for the regulatory period 2025-30, as informed by the results of CNAIM/CBRM modelling. It is essential to read this document in conjunction with the Instrument Transformer Asset Management Plan.

Asset categories covered under this business case are:

- Current Transformers (CT's)
- Voltage Transformers (VT's)
- Capacitive Voltage Transformers (CVT's)

3 BACKGROUND

The function of current transformers and voltage transformers in the electricity distribution and transmission system are to scale large values of current and voltage to appropriately lower standardised values for protection, system monitoring, and metering purposes. This is done to avoid damaging other integrated assets, as well as allowing the other associated assets such as protective relays to protect the network. Accordingly, instrument transformers play a critical role in the protection, measurement, and control of Energex's network, and failures or outages of instrument transformers can significantly degrade or prevent access to these important functions.

3.1 Asset Age Profile

Energex's instrument transformers population consist of Current Transformers (CT's), Voltage Transformers (VT's) and Capacitive Voltage Transformers (CVT's).

There are approximately 750 instrument transformers in the Energex Network (300 VTs & 450 CTs). VTs and CVTs are combined in the age profile in Figure 1 and Figure 2. It should be noted each VT or CT utilised for an individual phase are counted as a single unit in the age profile.

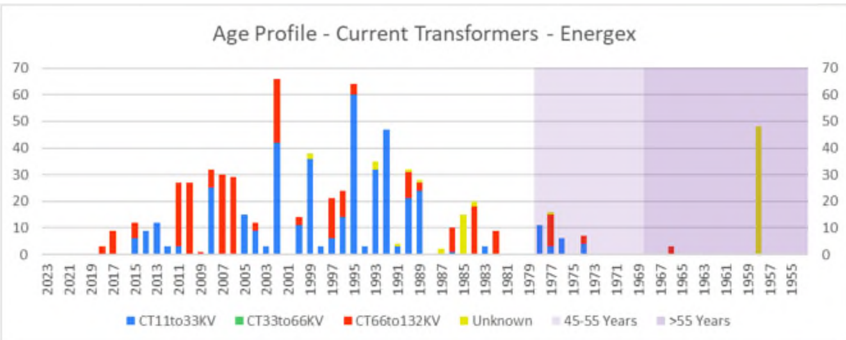

Figure 1: Age Profile - Current Transformers

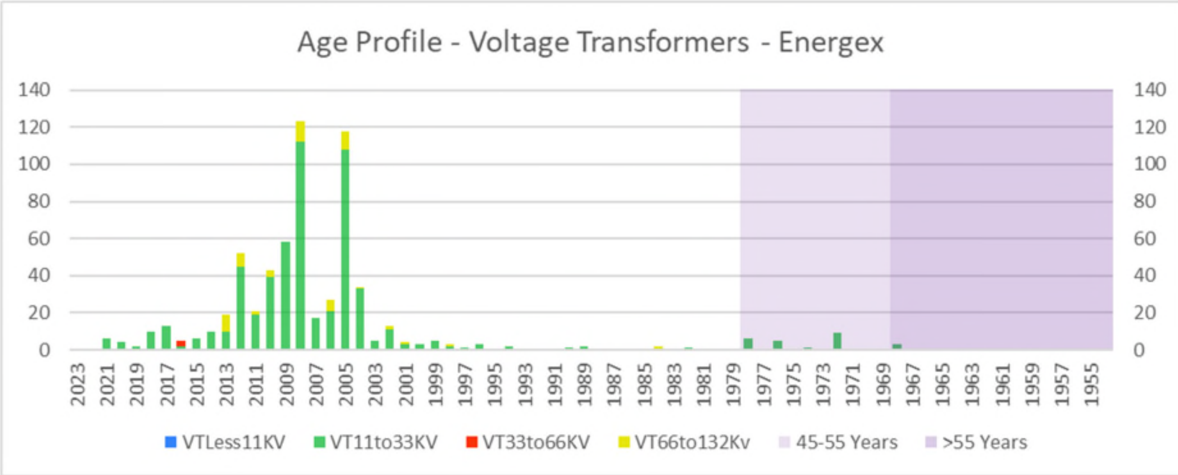

Figure 2: Age Profile - Voltage Transformers

3.2 Asset Management Overview

Energex adopts a number of strategies in managing the asset. These include:

- **Preventative maintenance** - which is performed in accordance with the inspection and Maintenance Standard Tasks with maintenance intervals outlined in the Maintenance Activity Frequency
- **Corrective maintenance** - undertaken when inspection and condition monitoring classify defects as outlined in the Lines Defect Classification Manual and Substation Defect Classification Manuals
- **Proactive replacement** - is the management strategy used in conjunction with Condition Based Risk Management to replace problematic assets.

3.3 Asset Performance

Two main functional failure modes considered in the business case and modelling are defined as:

- **Unassisted Catastrophic Failures:** Functional failure of an instrument transformer or component under normal operating circumstances and not caused by any external intervention such as abnormal weather or human.
- **Defects:** Instrument Transformer asset or component deemed defective based on prescribed classifications and if not rectified in a prescribed time scale (P0/P1/P2) could result in an unassisted failure.

Identified defects are scheduled for repair according to a risk-based priority scheme (P0/P1/P2). The P0, P1 and P2 defect categories relate to priority of repair, which effectively dictates whether normal planning processes are employed (P2), or more urgent repair works are initiated (P1 and P0).

Historical failure and defect data of instrument transformers are shown in Figure 3 and Figure 4 respectively. Defect data has shown some increasing trend recently while failure data has remained quite low and stagnant during last regulatory period indicating the effectiveness of current strategy and plans including condition monitoring and replacement programs for this asset class.

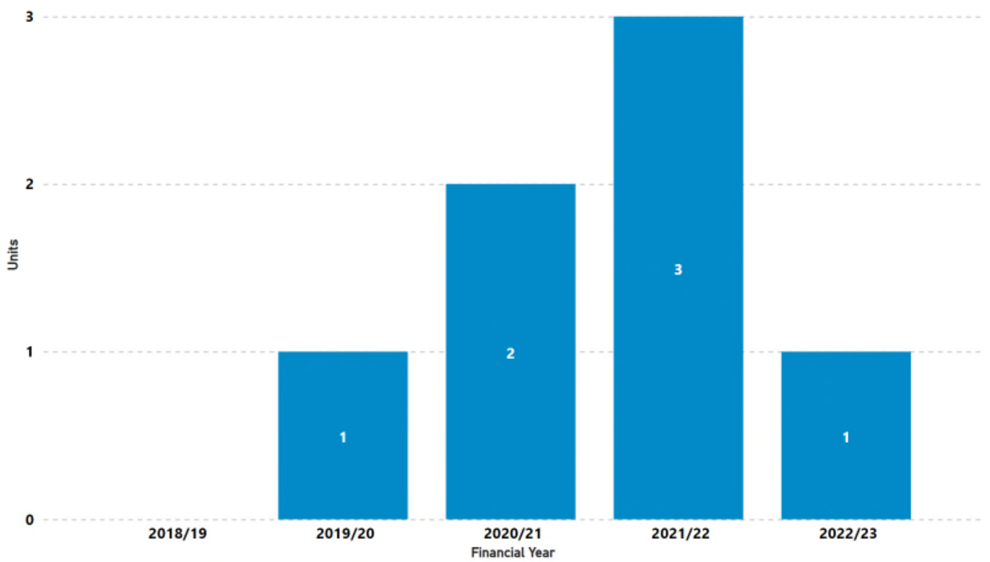

Figure 3: Unassisted Instrument Transformer Failures

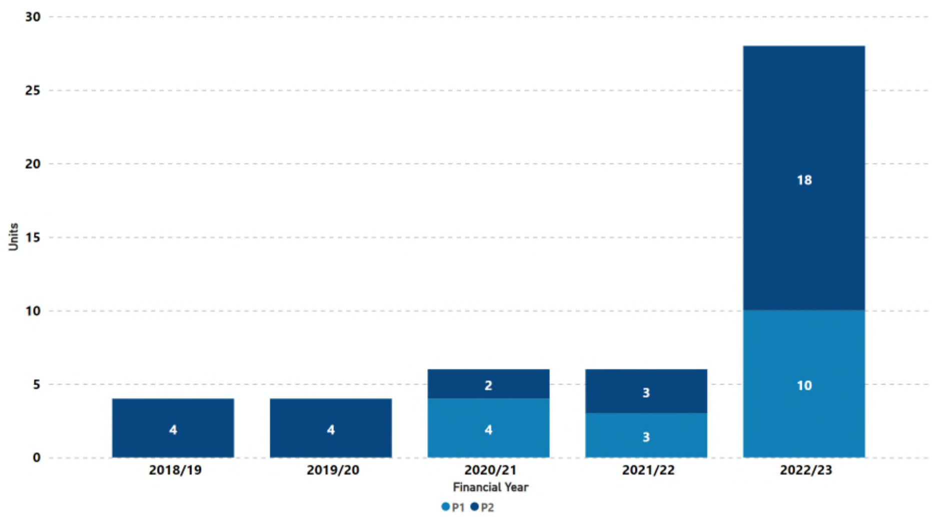

Figure 4: Instrument Transformer Defects

3.4 Risk Evaluation

The risk is calculated as per the equation in Figure 5.

Figure 5: Monetised Risk Calculations

Each consequence category follows the same calculations in Figure 5 to obtain the total monetised risk is as per Figure 6. Energex broadly considers five value streams for investment justifications regarding replacement of widespread assets. In Figure 6, only four of the value streams are considered; the 'Export' is not material to Instrument Transformers.

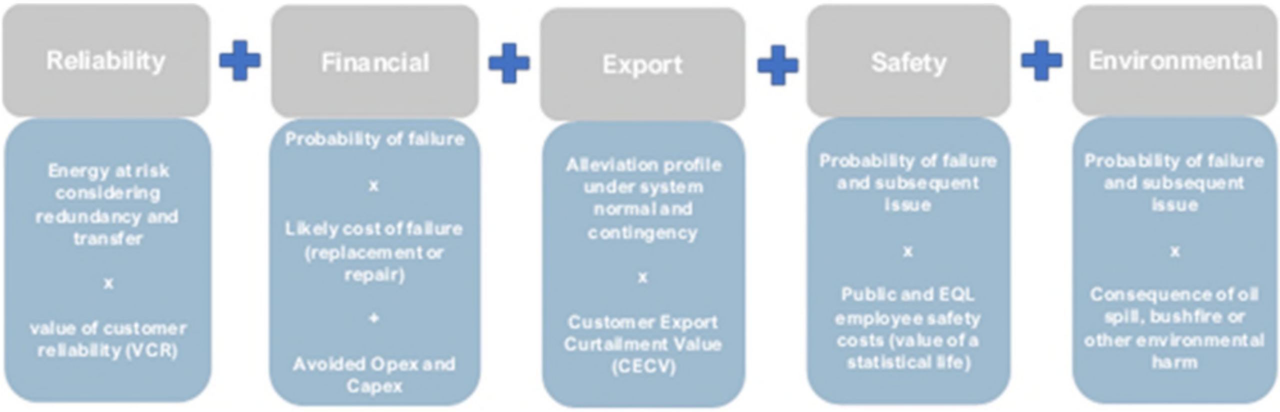

Figure 6: Total Risk Cost Calculations

3.4.1 Probability of Failure (PoF)

In order to determine the assets condition realistically, several contributing factors have been considered including appropriate probabilistic impact scales in line with Condition Based Risk Management (CBRM) and Common Network Asset Indices Methodology (CNAIM) principles. Both observed external deterioration (oil leaks, rust, corrosion etc) and measured condition data from Dissolved Gas Analysis (DGA) of oil samples, and bushings condition assessment and electrical testing has been incorporated into the determination of the Health Index (HI) for all Instrument Transformers to calculate the future probability of failure.

The PoF is calculated based on a well-established equation set out in CBRM/CNAIM modelling after analysing worldwide data about the relationship between health index and PoF for different assets.

3.4.2 Consequence of Failure (CoF)

Consequences of an in-service failure has been assessed across four value streams and are relevant to this business case:

- **Reliability:** There will be unserved energy following the in-service failure of an instrument transformer. The network performance is also monitored through SAIDI and SAIFI performance of the distribution network – a key performance indicator for the business and community
- **Financial:** There will be a financial cost associated with responding to a failed instrument transformer, as well as replacing the transformer under emergency. The unplanned cost could vary significantly from couple of thousands to hundreds of thousands depending on size of the transformer, type of the fault and the damage occurred to the transformer or associated components such as bushings or tanks
- **Safety:** There is a risk of multiple serious injuries or fatality following a failure of an instrument transformer, specifically old assets with porcelain bushings, dependent on the failure mode and proximity of the employee/contractor during the event. Considering that these transformers are installed within security fences, public injuries are very rare and therefore not considered in the risk assessment
- **Environmental:** There is a moderate risk of environmental impact/contamination under right conditions in case of failure of an instrument transformer due to oil leaks

3.4.3 Likelihood of Consequence (LoC)

Likelihood of consequence refers to the probability of a particular outcome or result occurring because of a given event or action. To estimate the likelihood of consequence, Energex has utilised a combination of historical performances and researched results. Energex has analysed past events, incidents, and data to identify patterns and trends that can provide insights into the likelihood of similar outcomes occurring in the future. Additionally, Energex also has conducted extensive research to gather relevant information and data related to the respective risk criteria.

4 IDENTIFIED NEED

4.1 Problem and/or Opportunity

Energex has experienced a number of catastrophic failures associated with particular CVTs. Failure of these assets poses a safety risk to personnel, due to injury from porcelain bushing fragments as a result of asset explosion. Additionally, network reliability is affected if adjacent plant equipment is damaged by an exploding instrument transformer inside the switchyard.

Energex is in the process of establishing voltage monitoring and alarming across the population of 110kV and 132kV CVTs, which is planned to be completed this regulatory period. The functionality has been delivered within the SCADA system and the alarm thresholds are currently being established in consideration of regional alignment.

Maintenance and testing of stand-alone instrument transformers are conducted regularly, with the performance against defined criteria monitored, and issues addressed to ensure these assets reach the end of their economic life.

4.2 Compliance

The assets described in this business case are not specifically referenced in legislation, and therefore are expected to achieve general obligations surrounding asset safety and performance and service delivery. These obligations include compliance with all legislative and regulatory standards, including the Queensland Electrical Safety Act 2002 and the Queensland Electrical Safety Regulation 2013 (ESR).

Under its distribution licences, Energex is expected to operate with an 'economic' customer value-based approach to reliability, with "Safety Net measures" aimed at managing low probability high consequence outage risks. Energex is expected to employ all reasonable measures to ensure it does not exceed minimum service standards (MSS), assessed by feeder type, as:

- System Average Interruption Duration Index (SAIDI)
- System Average Interruption Frequency Index (SAIFI)

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.

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

Accordingly, this asset class is managed, consistent with corporate asset management policy, to achieve all legislated obligations and any specifically defined corporate key performance indicators, and to support all associated key result areas as reported in the Statement of Corporate Intent (SCI).

5 ASSET LIMITATION FORECAST SUMMARY

5.1 Asset Condition Limitations – Health Index (HI) Summary

Energex uses condition-based risk management (CBRM) to predict the end of life of Substation Instrument Transformers. CBRM uses age, location, and condition to predict the health of the asset as an index (Health Index – HI) that has a range of 1 – 9. A higher HI value represents a more degraded asset as illustrated in Figure 7.

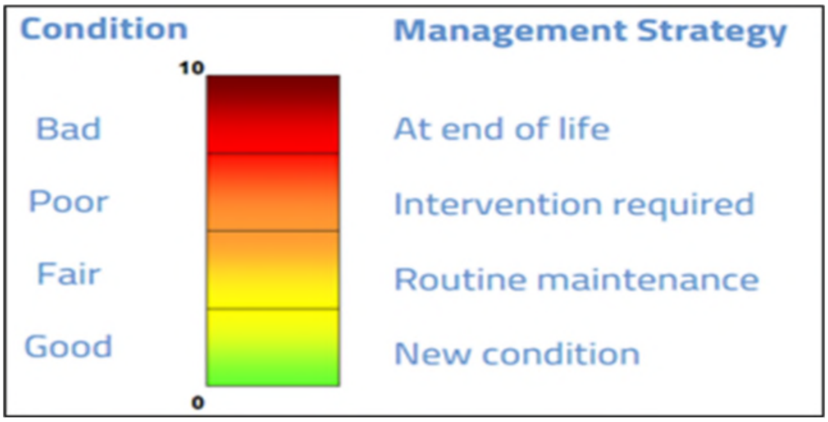

Figure 7: Health Index and Condition Relationship

Energex considers assets for replacement when HI reaches 7.5. The asset management plan documents the basis of the condition analysis and derivation of health index. The network risk framework is applied to prioritise asset replacement at a program level within financial and resource constraints.

Since instrument transformers that have exceeded their expected life does not necessarily mean they pose a high risk, they considered for replacement to avoid an unsustainable build-up of aged assets. These particular replacements will be based on network requirements aligned with other network drivers such as network augmentation or customer driven projects.

The current heath index profile of instrument transformers is found in Figure 8. Although current HI indicates that none of the transformers have a HI over 7.5 therefore no intervention is expected at present. As per Figure 9, by 2030 a total of 38 instrument transformers would exceed the HI of 7.5.

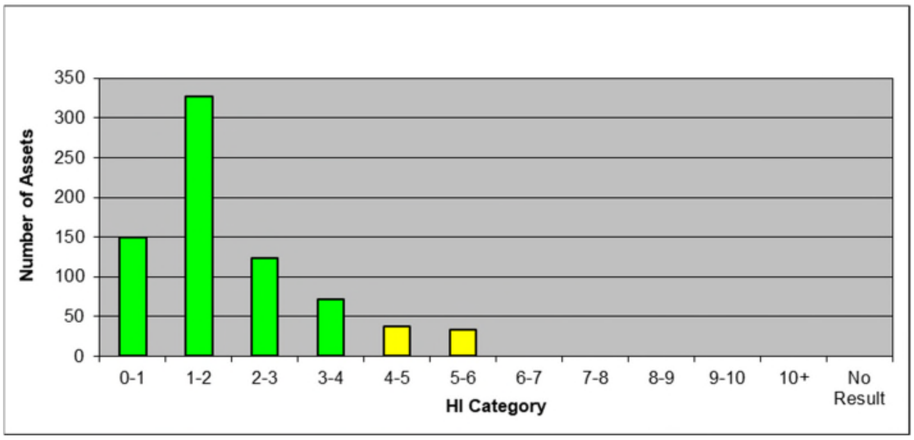

Figure 8: Current HI Summary 2022-23

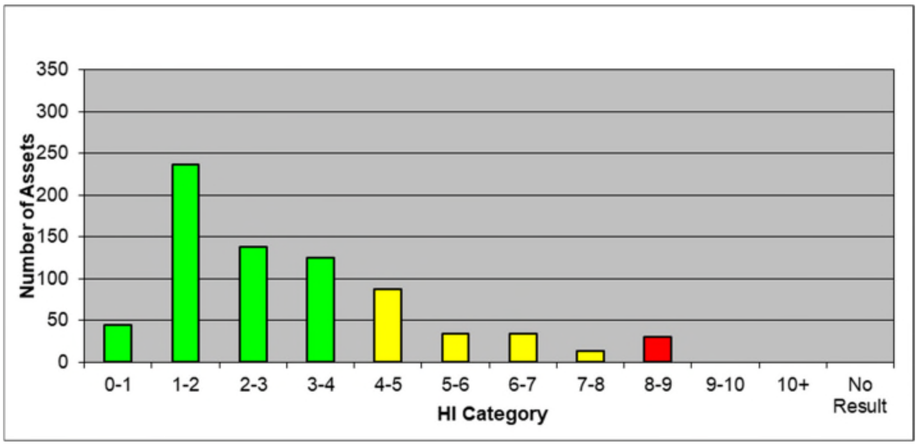

Figure 9: Future Forecast HI Summary 2029-30

5.2 Optimal Timing and NPV analysis

This Business Case presents asset limitations in terms of CBRM modelling outcomes as per descriptions in Section 5.

However, the optimal timing of replacement of an asset, NPV analysis, risk evaluation and bundling of works with other poor condition network assets at a specific time shall be carried out in case-by-case basis under each individual projects based on overall prudency and efficiency to minimise the cost impact on customers/community.

Refer to the individual project proposals for NPV, risk evaluation and cost benefits outcomes.

5.3 Asset Replacement Limitation Forecast

Based on CBRM modelling and HI calculations, a total of 8 per annum are forecast to be replaced during the period 2025-30 as per Table 1.

Year	2025/26	2026/27	2027/28	2028/29	2029/30	Total
Quantity	7	7	8	8	8	**38**

Table 1: Replacement Volume Summary – AER 2025-30 – CBRM Modelling

Furthermore, based on the risk evaluation, optimal timing and NPV analysis for individual projects is provided in Table 2.

Year	2025/26	2026/27	2027/28	2028/29	2029/30	Total
$m, direct 2022-23	1.1	1.5	0.7	0.9	0.7	4.9
Quantity	1	0	46	0	41	88

Table 2: Proposed Replacement Program– RIN Forecast

The majority of these replacements are in combination with the replacement of our circuit breakers in zone substation. In general, these assets are integral with the circuit breaker, and so where these are required for replacement, our instrument transformers are replaced as a matter of course. This can be seen from the very low unit cost implied from Table 2.

6 RECOMMENDATION

The proposed volume provides the best balance of benefits and risks for the organisation. As such, the decision has been made to step change in proactive replacement volume, with a focus on optimizing existing processes and enhancing efficiencies where possible.