Substation Transformer Replacements

Business Case

19 January 2024

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DOCUMENT VERSION

Version Number	Change Detail	Date	Updated by
Draft v0.1	AER Document Initial Release	31/05/20223	Senior Asset Strategy Engineer
Draft v0.2	Finalised Draft – Formatted	14/11/2023	Manager Asset Strategy
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RELATED DOCUMENTS

Document Date	Document Name	Document Type
JAN 2024	Asset Management Plan – Substation Transformers	PDF
NOV 2023	Substation Transformers CBRM/CNAIM Model	Excel
28/07/2023	Network Risk Framework ID2877290	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
AUG 2023	Maintenance Activity Frequency (MAF) – Release 2	PDF

1 SUMMARY

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<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 report is to outline the projected limitations for substation transformer assets in alignment with the lifecycle management approaches specified in the Asset Management Plan Substation Transformers. Additionally, this Business Case provides the overview of interventions, both in terms of volume and financial allocations during the regulatory period 2025-30, as informed by the results of CNAIM/CBRM modelling.

Substation Transformers are critical to the distribution network due to the large energy transfer requirements, failure of these assets can substantially influence reliability performance. These assets feature prominently in Safety Net contingency plans required by EQL's/Energex Distribution Licences. EQL/Energex employs all reasonable measures to ensure it does not exceed minimum reliability service standards, assessed as:
• System Average Interruption Duration Index (SAIDI)
• System Average Interruption Frequency Index (SAIFI).</td></tr>
<tr><td>Expenditure</td><td>
<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>2025-30</th></tr>
<tr><td>$m, direct 2022-23</td><td>2.5</td><td>5.7</td><td>8.1</td><td>10.9</td><td>7.3</td><td>34.5</td></tr>
<tr><td>Volume</td><td>1</td><td>2</td><td>2</td><td>6</td><td>9</td><td>20.0</td></tr>
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</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 Substation 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. Energex ensures 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 Substation Transformers. Business cases for those investments are available on request.</td></tr>
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2 PURPOSE AND SCOPE

The objective of this business case document is to define the projected limitations related to Substation Transformers 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 Asset Management Plan - Substation Transformers.

3 BACKGROUND

Substation Transformers are critical to the distribution network due to the large energy transfer capability. Failure of these assets can substantially influence our reliability performance. These assets feature prominently in Safety Net contingency plans required by Energex's Distribution Authority. Energex employs all reasonable measures to ensure it does not exceed minimum reliability service standards, assessed as:

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

Energex employs a regime of periodic inspections and intrusive maintenance practices in alignment with the maintenance strategies to efficiently manage our substation transformer assets. The CBRM/CNAIM model used by Energex leverages these observed and measured conditions from maintenance and inspection to predict the assets' end-of-life scenarios.

3.1 Asset Population

There are a total of 578 substation transformers in service. Without replacements, by 2029-30 there will be 77 transformers over 50 years old, including 32 transformers over 60 years old. This is shown in Figure 1.

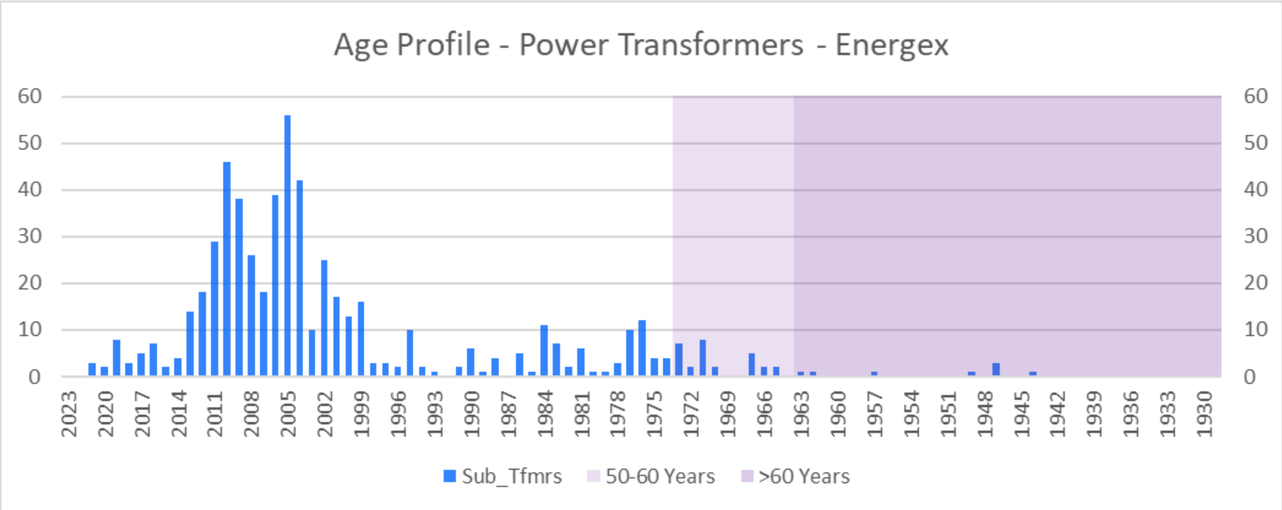

Figure 1: Age Profile – Substation Transformers

3.2 Asset Management Overview

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

- **Preventative maintenance:** which is performed in accordance with the inspection and intrusive 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 and Substation Defect Classification Manuals.
- **Proactive Replacement**: is the management strategy used in conjunction with Condition Based Risk Management (CBRM/CNAIM) model to replace assets.
- **Reactive Replacement**: occurs when the asset has failed, and this is to be avoided as it has negative safety, reliability. and reputational impact.

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 a substation transformer or component under normal operating circumstances and not caused by any external intervention such as abnormal weather or human.
- **Defects:** Substation 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 data has been provided in the Figure 2 while the defect data has been provided in Figure 3. Failure data has shown a small jump in volume and currently being investigated, while the defect data has indicated a downward trend since 2019-20 after a jump in 2019-20. The consistent failure and defects data indicate the effectiveness of the current strategy, condition monitoring, and management of substation transformers assets suggesting no major change in strategy or replacement volumes is required at this stage.

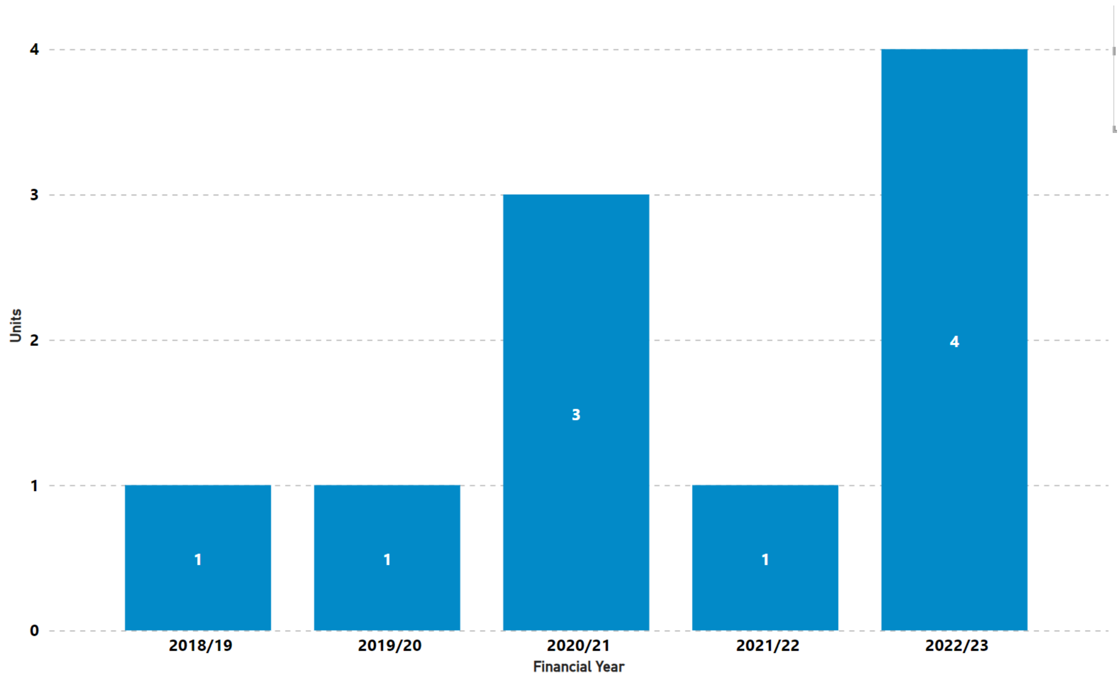

Figure 2: Unassisted Failures

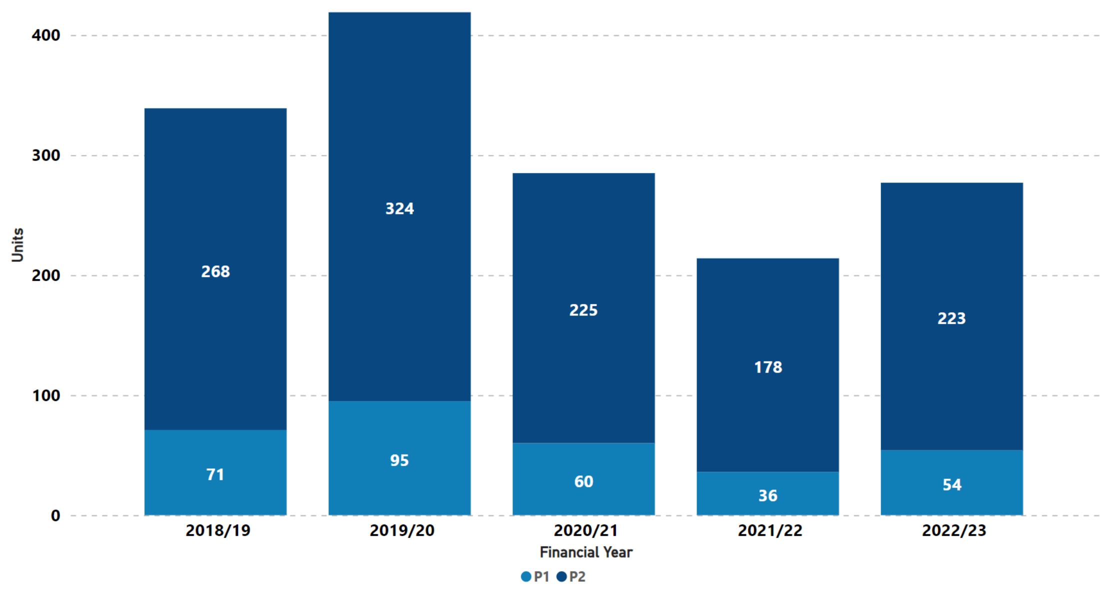

Figure 3: Priority 1 and 2 Defects on Energex Transformers

3.4 Risk Evaluation

The risk is calculated as per equation in Figure 4.

Annual Asset-Risk Cost ($) = **Probability of Failure (PoF)** × **Asset Units (No.)** × **Likelihood of consequence of failure event (LoC)** × **Consequence cost of failure event (CoC)**

Figure 4: Monetised Risk Calculations

Each consequence category follows the same calculations in Figure 4 to obtain the total monetised risk as per Figure 5. Energex broadly considers five value streams for investment justifications regarding replacement of widespread assets. In Figure 5 only four of the value streams are considered.

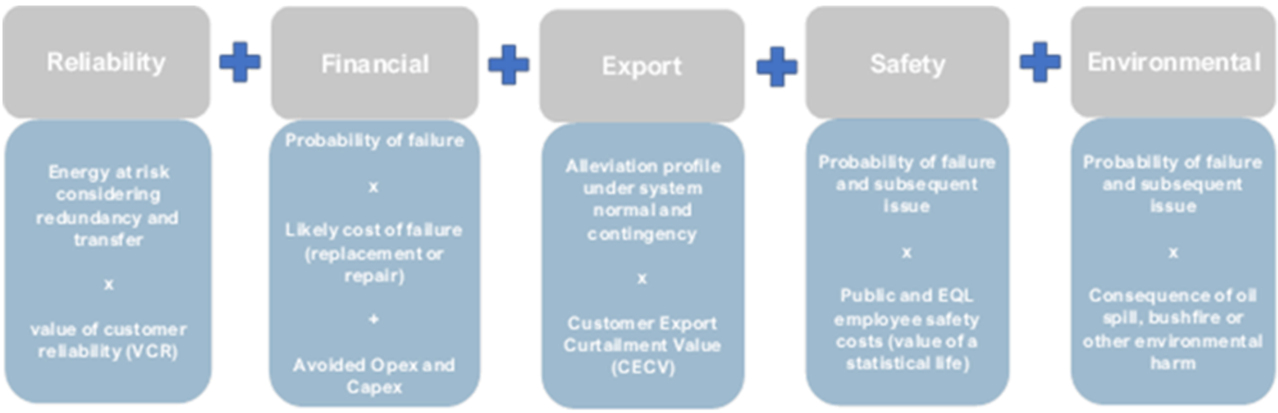

Figure 5: Total Risk Cost calculations

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, tap-changer and bushings condition assessment and electrical testing have been incorporated into the determination of the Health Index (HI) for all PTs 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 on the relationship between health index and PoF for different assets.

3.4.2 Consequence of Failure (CoF)

Consequences of an in-service failure have 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 a Substation 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 Substation Transformer, as well as replacing the Transformer under emergency. The unplanned cost could vary significantly from a couple of thousands to millions of dollars depending on the size of the transformer, type of the fault, and the damage occurred to the transformer or associated components such as tap-changers, bushings, tanks or cooling systems.
- **Safety:** There is a risk of multiple serious injuries or fatality following a failure of a Substation 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 have not been considered in the risk assessment.
- **Environmental:** There is a considerable risk of environmental impact/contamination under the right conditions in the case of failure of a Substation Transformer. A Substation Transformer contains the largest volume of oil, present at site.

3.4.3 Likelihood of Consequence (LoC)

The 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 Statement

Substation Transformer assets are a significant portion of the Energex distribution network and are critical in ensuring its reliability. Energex objectives as a company, is to provide energy solutions to consumers in a way that is sustainable, secure, and environmentally considerate whilst also being affordable.

Energex have a moderate quantity of older Substation Transformer and regulator assets. This is likely due to the managing sustainable replacement volume in history and Energex plan to continue with the counterfactual strategy as proposed.

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. Loss of Substation Transformers, Regulators, or Reactors is usually a significant event and may require Safety Net contingency plans to be exercised.

Both Safety Net and MSS performance information is publicly reported annually in the Distribution Annual Planning Reports (DAPR). The National Electricity Rules (NER) require that the voltage magnitudes at all energised busbars at any substation be within the relevant limits set by the relevant NSP, and within ± 10% of normal supply voltage.

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 Transformers. CBRM uses age, type, model, location, duty, and condition to predict the health of the asset as an index (Health Index – HI) that has a range of 0 – 10. A higher HI value represents a more degraded asset as illustrated in Figure 6.

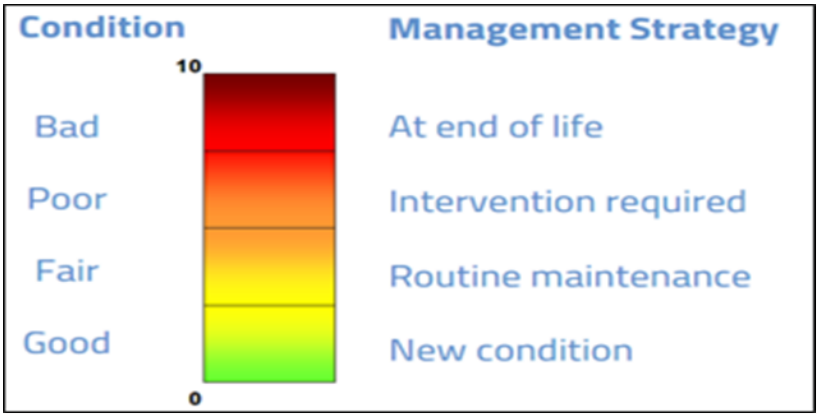

Figure 6: Health Index and Condition Relationship

Energex employs a structured approach to asset replacement, utilizing a Health Index (HI) threshold of 7.5 as the trigger point for consideration. The CBRM documentation details the methodology for assessing asset condition and determining the HI. After the derivation of asset limitation from CBRM, we utilise the Network Risk Framework to prioritise asset replacement, accounting for financial and resource constraints.

To identify assets in the poorest condition, Energex utilises the CBRM modelling. Additionally, older substation transformers that have surpassed their technical life are earmarked for potential replacement to prevent the accumulation of aging assets. Replacement decisions for these candidate assets are made in conjunction with network requirements and other factors, such as augmentation and customer-requested projects. This ensures the most cost-effective solution from a holistic network perspective. Network Risk Framework is applied at the individual project level to further guide replacement decisions within the defined constraints.

Figure 7 presents the latest HI data for substation transformers with an HI of 7.5 signifying poor asset condition requiring intervention within a specified timeframe. Notably, this figure indicates that approximately 13 assets currently have an HI exceeding 7.5, necessitating intervention in the next few years.

Furthermore, Figure 8 provides an estimated forecast of the HI summary for substation transformers at the end of the modelling period (year 2030), as determined by CBRM. It highlights that 50 assets are projected to exceed the HI threshold of 7.5, underscoring the need for a proactive replacement program over the next few years, including within the current regulatory period, to effectively manage this risk.

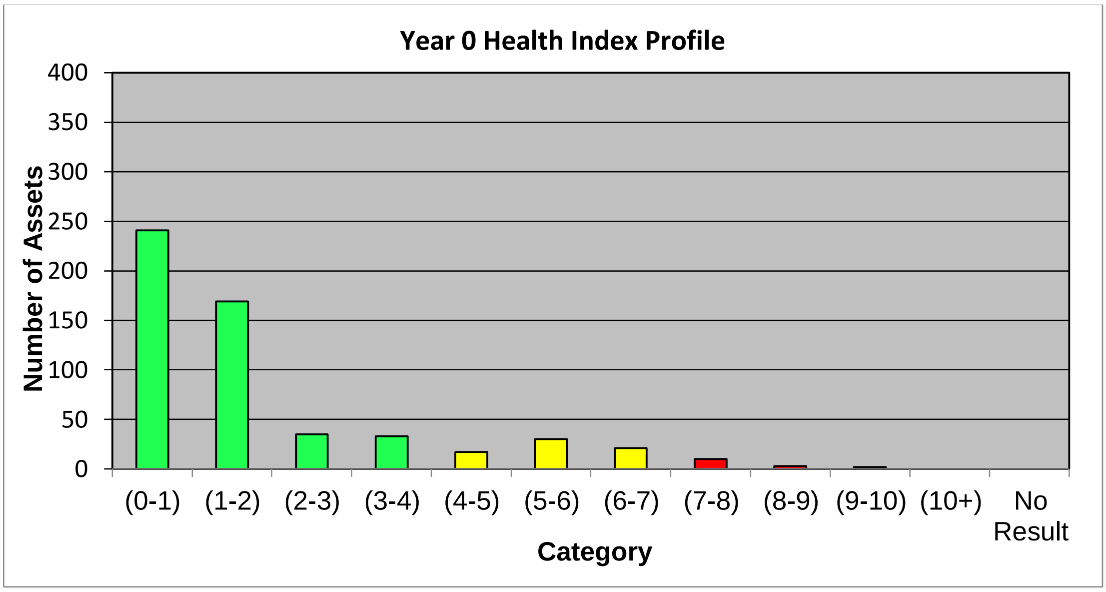

Figure 7: Year 0 Health Index Summary

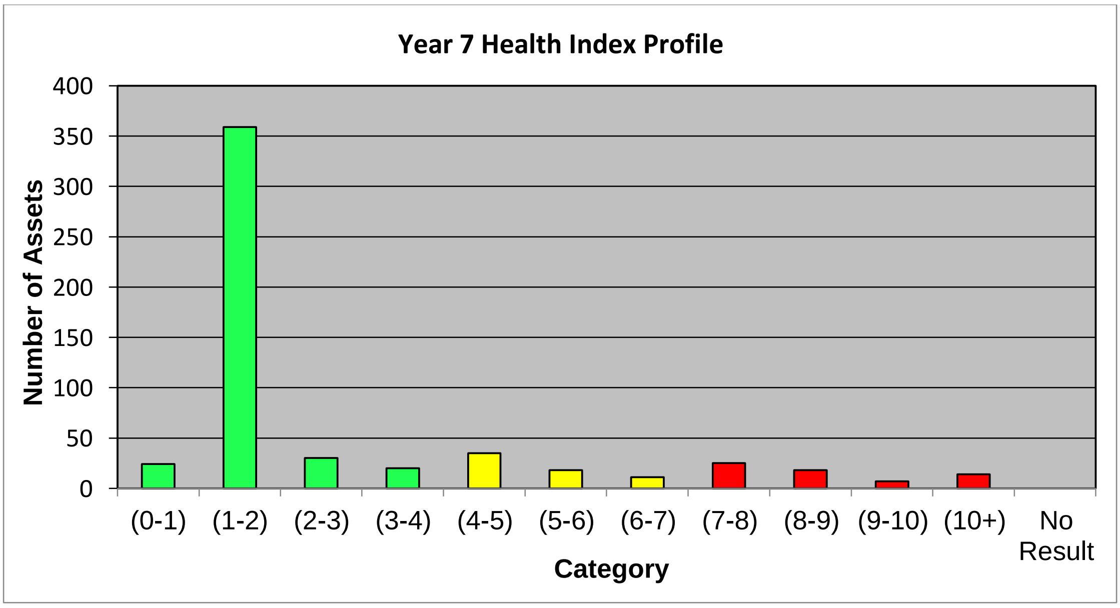

Figure 8: Year 7 Health Index Summary

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 a case-by-case basis under each individual projects based on overall prudency and efficiency to minimise the cost impact on customers/community.

Individual sites are assessed, and projects created where there is a positive NPV, risk evaluation and cost benefits outcome.

5.3 Asset Replacement Limitation Forecast

Based on CBRM modelling and HI calculations, a total of 10 Substation Transformers 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	19	3	12	3	13	**50**

Table 1: Substation Transformer Replacement Summary -CBRM Modelling

After conducting the risk evaluation, optimal timing and NPV analysis for individual projects to optimise the cost/benefits for the community, the proposed modified volume summary and expenditure are shownd in Table 2.

Year	2025/26	2026/27	2027/28	2028/29	2029/30	Total
$m, direct 2022-23	2.5	5.7	8.1	10.9	7.3	**34.5**
Quantity	1	2	2	6	9	**20**

Table 2: Substation Transformer Replacement Volumes - RIN Forecast

Projects that we have included in our proposal that have substation transformer replacements include:

- Stafford Zone Substation Transformer and Circuit Breaker Replacement
- Loganholme Zone Substation Transformer and Circuit Breaker Replacement
- Redbank Zone Substation Transformer and Isolators Replacement
- North Pine Damn Zone Substation Transformer and Switchgear Replacement
- Booval Zone Substation Transformer and VT Replacement
- Kallangur Zone Substation Transformer Replacement
- Tarampa Transformer Replacement
- Miami Zone Substation Transformer Replacement
- Coominya Zone Substation Transformer Replacement
- Raby Bay Transformer Replacement
- Bundall Zone Substation Transformer Replacement
- Jindalee Zone Substation Transformer Replacement
- Belmont Zone Substation Transformer Replacement
- Lockrose Zone Substation Transformer Replacement
- Kirra Zone Substation Transformer and Circuit Breaker Replacement
- Wivenhoe Zone Substation Transformer Replacement

6 RECOMMENDATION

The proposed volume provides the best balance of benefits and risks for the organisation. As such, we are forecasting the replacement of 20 zone substation transformers in the 2025-2030 regulatory control period.

Part of Energy Queensland

7 APPENDIX – RESET RIN RECONCILIATION

	2025/26	2026/27	2027/28	2028/29	2029/30	Total
	Expenditure	Expenditure	Expenditure	Expenditure	Expenditure	Expenditure
$, direct 2022-23	2.5	5.7	8.1	10.9	7.3	**34.50**
$, direct 2024-25	2.8	6.5	9.3	12.5	8.4	**39.53**

Table 3: RESET RIN Reconciliation Table