Substation Transformer Replacements

Business Case

22 January 2024

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DOCUMENT VERSION

Version Number	Change Detail	Date	Updated by
Draft v0.1	Initial Release	31/10/2023	Engineer Asset Strategy
Draft v0.2	Draft Review Post Feedback	14/11/2023	Snr Engineer Asset Strategy
V1.0	Approved	15/11/2023	Manager Asset Strategy

RELATED DOCUMENTS

Document Date	Document Name	Document Type
JAN 2024	Asset Management Plan – Substation Transformers	PDF
NOV 2023	Substation Transformers CBRM/CNAIM Model	Excel
JUN 2023	RIN 2.2 Compare 2021-22 (Rosetta)	Excel
NOV 2023	Ergon 2022-23 - Category Analysis - RIN Response - Consolidated - 23 November 2023 – PUBLIC (16058117.2)	Excel
AUG 2023	Maintenance Activity Frequency (MAF) – Release 2	PDF
JUN 2023	Maintenance Acceptance Criteria (MAC) – Release 11	PDF
OCT 2023	Lines Defect Classification Manual	PDF
JUL 2023	Substation Defect Classification Manual	PDF

1 SUMMARY

<table>
<tr><th>Title</th><th>Substation Transformer Replacements</th></tr>
<tr><td>DNSP</td><td>Ergon Energy Network</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 report is to outline the projected limitations pertaining to substation transformer assets in alignment with the lifecycle management approaches specified in the Asset Management Plan. 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.

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 Distribution Licences. EQL 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)

Ergon Energy have a significantly higher quantity of older Substation Transformer and regulator assets. This is likely due to the typically lower loads that the assets have been required to supply, and the resultant extension on their useful life. While life extension of the asset is desirable, the proportion of assets that have exceeded the expected life presents a risk that needs to be monitored and managed in order to meet asset management objectives.</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>11.0</td><td>14.6</td><td>16.9</td><td>22.7</td><td>26.7</td><td>91.9</td></tr>
<tr><td>Volume</td><td>4</td><td>7</td><td>21</td><td>6</td><td>17</td><td>55</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 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. Ergon 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>
</table>

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 requirements, failure of these assets can substantially influence reliability performance. These assets feature prominently in Safety Net contingency plans required by Ergon's Distribution Authority. Ergon 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)

Ergon Energy have a significantly higher quantity of older Substation Transformer and regulator assets. This is likely due to the typically lower loads that the assets have been required to supply, and the resultant extension on their useful life. While life extension of the asset is desirable, the proportion of assets that have exceeded the expected life presents a risk that needs to be monitored and managed in order to meet asset management objectives.

Ergon Energy employs a regime of periodic inspections and intrusive maintenance practices in alignment with our maintenance strategies to efficiently manage our substation transformer assets. The CBRM/CNAIM model used by Ergon Energy 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 number of 604 Substation Transformers in service and in 2029-30 there will be 117 transformers over 60 years. This is shown in Figure 1.

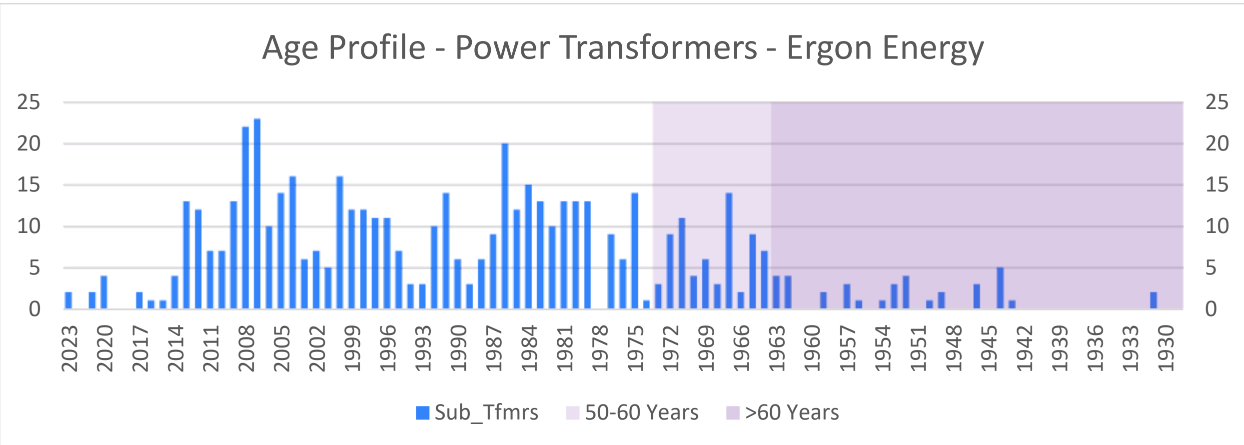

Figure 1: Substation Transformer Age Profile – Ergon Energy

3.2 Asset Management Overview

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

- **Preventative Maintenance:** 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 the modelling are defined as:

- **Unassisted Catastrophic Failures:** Functional failure of a substation transformer asset 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).

The most recent last five-year unassisted failures and defects (P1 and P2) data related to Substation Transformers in Ergon Energy has been provided in Figure 1, and Figure 2 respectively. These failure graphs indicate a considerable increase in failures during the last two years, while the defect data has been steadily high. Please refer to Section 5 for further details on health condition and risk limitations summary as per CNIAM/CBRM modelling.

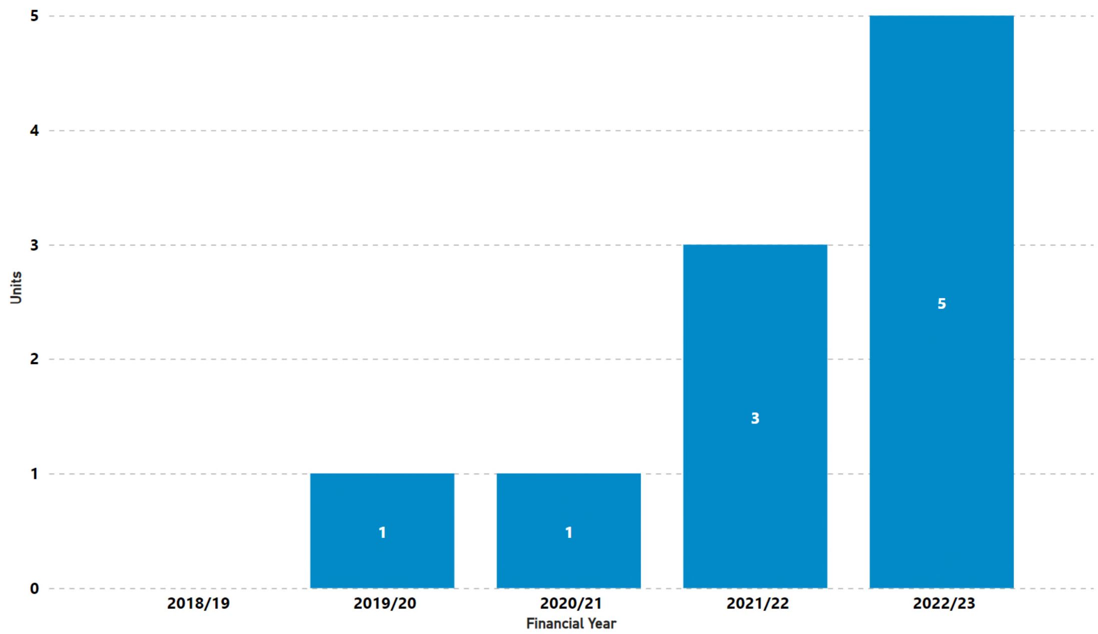

Figure 2: Unassisted Substation Transformer Failures

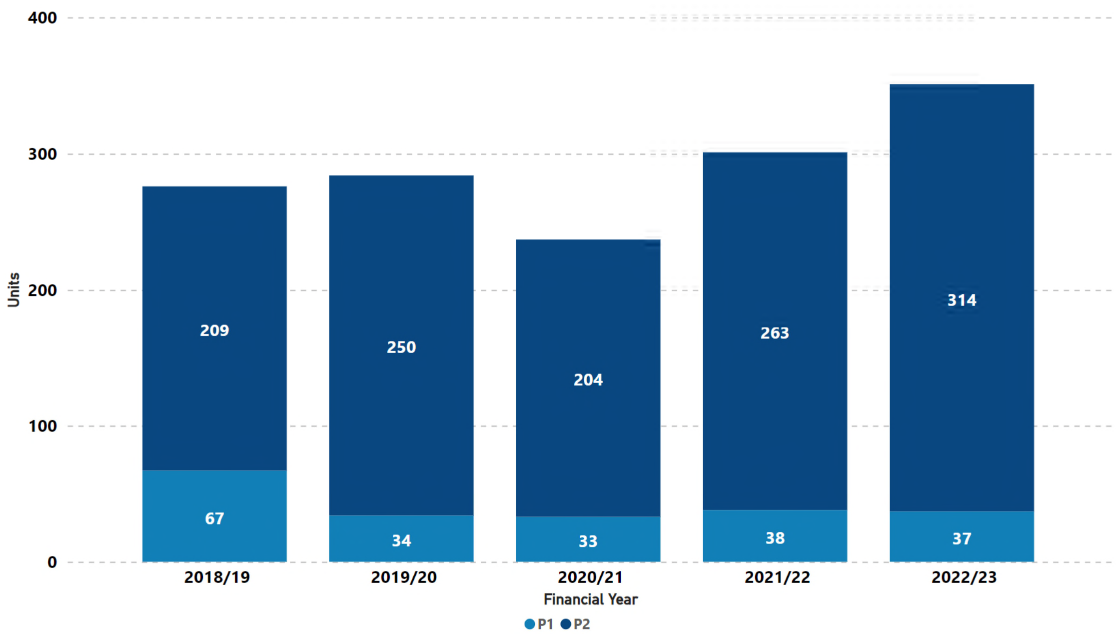

Figure 3: Priority 1 and 2 Defects on Ergon Energy Substation Transformers

3.4 Risk Evaluation

The risk is calculated as per equation in Figure 4:

Figure 4: Monetised Risk Calculations

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

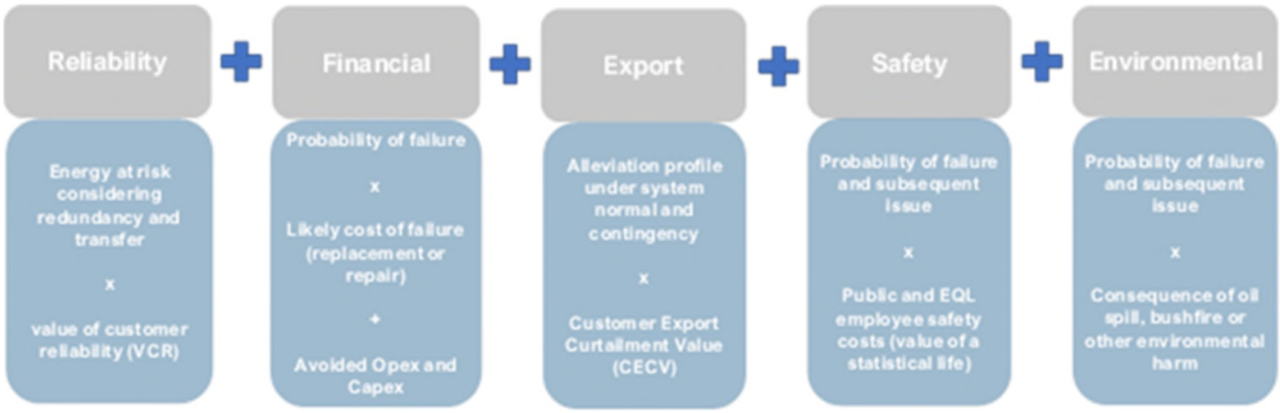

Figure 5: Total Risk Cost calculations

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 has 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 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 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 couple of thousands to millions depending on size of the transformer, type of the fault and the damage occurred to the transformer or associated components such as tap-changer, 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 has not been considered in risk assessment.
- **Environmental:** There is a considerable risk of environmental impact/contamination under right conditions in case of failure of a Substation Transformer. A Substation Transformer contains largest volumes 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, Ergon Energy has utilised a combination of historical performances and researched results. Ergon Energy 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, Ergon Energy 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 Ergon Energy distribution network and are critical in ensuring its reliability. Ergon Energy's objective as a company is to provide energy solutions to consumers in a way that is sustainable, secure, and environmentally considerate whilst also being affordable.

Ergon Energy have a significantly higher quantity of older Substation Transformer and regulator assets. This is likely due to the typically lower loads that the assets have been required to supply and the resultant extension on their useful life. While life extension of the asset is desirable, the proportion of assets that have exceeded the expected life presents a risk that needs to be monitored and managed in order to meet asset management objectives.

4.2 Compliance

The assets described in this business case are not specifically referenced in the legislation, and therefore are expected to achieve general obligations surrounding asset safety, 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, EQL 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. EQL 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%.

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

EQL uses condition-based risk management (CBRM) to predict the end of life of Substation Transformers. CBRM uses age, 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.

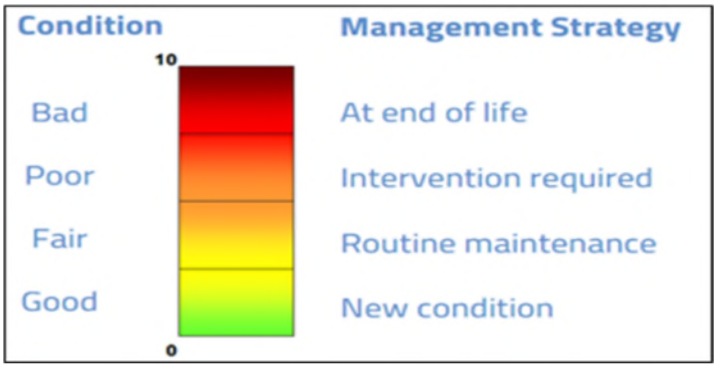

Figure 6: Health Index and Condition Relationship

Ergon Energy 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 Ergon Energy Risk Framework to prioritise asset replacement, accounting for financial and resource constraints.

To identify assets in the poorest condition, Ergon Energy utilises 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 and refurbishment decisions for these candidate assets are made in conjunction with network requirements and other factors, such as augmentation and customer-requested projects, ensuring the most cost-effective solution from a holistic network perspective. The Ergon Energy 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 9 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 111 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.

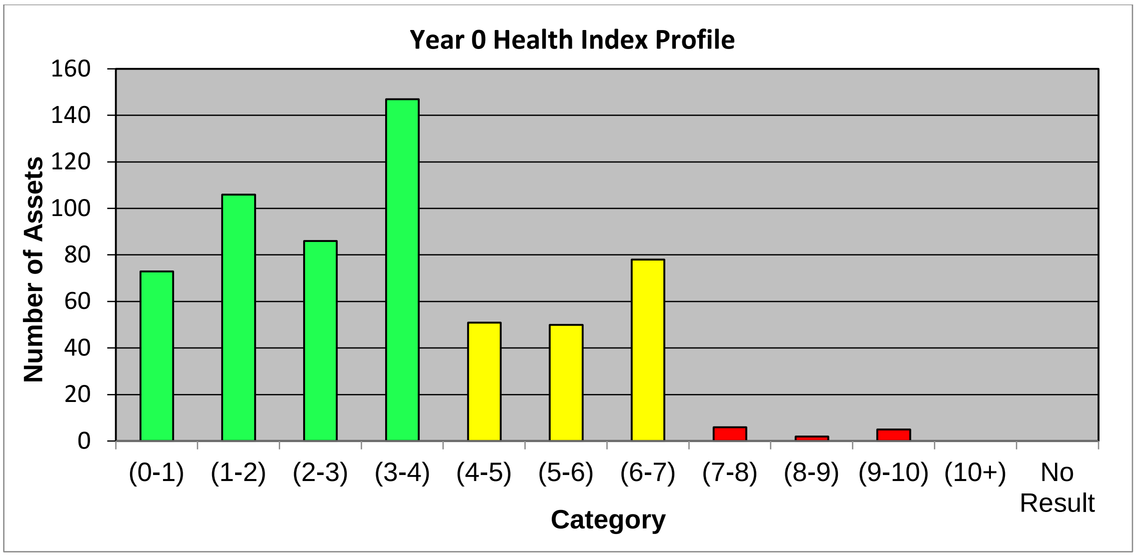

Figure 7: Year 0 Health Index Summary

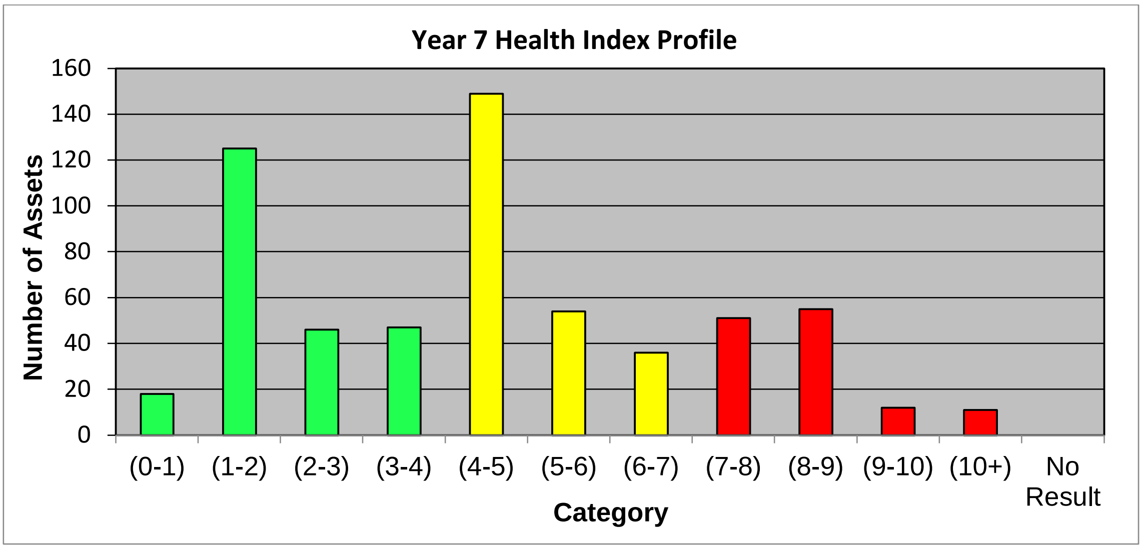

Figure 8: Year 7 Health Index Summary

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 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 AER 2025-30

Based on CBRM modelling and Health index calculations the proposed replacement volumes for Substation Transformers have been provided in Table 1.

Year	2025/26	2026/27	2027/28	2028/29	2029/30	Total
Quantity	2	8	25	32	24	**111**

Table 1: Substation Transformers Replacement Volumes- CBRM modelling

Furthermore, after conducting the risk evaluation, optimal timing and NPV analysis for individual project to optimise the cost/benefits for the community the proposed modified volume summary and expenditures have been provided in Table 2.

Year	2025/26	2026/27	2027/28	2028/29	2029/30	Total
$m, direct 2022-23	11.0	14.5	16.8	22.6	26.6	**91.5**
Quantity	4	7	21	6	17	**55**

Table 2: Substation Transformer Proposed Replacement Program – RIN Forecast

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

- Neil Smith Zone Substation Transformer and Circuit Breaker Replacement
- Ayr Zone Substation Transformer Replacement
- Degilbo Zone Substation Transformer and Circuit Breaker Replacement
- Pialba Zone Substation Transformer and Switchgear Replacement
- Jarvisfield Substation Transformer Replacement
- Ingham Zone Substation Transformer Replacement
- South Kolan Transformer and Switchgear Replacement
- Douglas Shire Transformer and Switchgear Replacement
- Theodore Zone Substation Transformer Replacement

6 RECOMMENDATION

The proposed volume provides the best balance of benefits and risks for the organisation with a focus on optimizing existing processes and enhancing efficiencies where possible to deliver optimal outcome for our customers. Forecasted replacement volume reflects the assets with greatest risk based on the asset condition, safety and reliability of each transformer.

APPENDIX –– RESET RIN RECONCILIATION

	2025/26	2026/27	2027/28	2028/29	2029/30	Total
	Expenditure	Expenditure	Expenditure	Expenditure	Expenditure	Expenditure
$, direct 2022-23	11.0	14.6	16.9	22.7	26.7	**91.90**
$, direct 2024-25	12.5	16.7	19.4	26.1	30.9	**105.70**

Table 3: RESET RIN Reconciliation Table