Underground Cable Replacements

Business Case

19 January 2024

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DOCUMENT VERSION

Version Number	Change Detail	Date	Updated by
Draft v0.1	Initial draft	10/03/2023	Asset Strategy Engineer
Draft v0.2	Initial Release	31/05/2023	Senior Asset Strategy Engineer
Draft v0.3	Finalised Draft – Formatted	02/11/2023	Manager Asset Strategy
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RELATED DOCUMENTS

Document Date	Document Name	Document Type
JAN 2024	Asset Management Plan – Underground Cables	PDF
NOV 2023	Underground Cable CBRM/CNAIM Model	Excel
JAN 2024	Lines Defect Classification Manual (LDCM)	Manual
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
JUN 2023	Maintenance Acceptance Criteria (MAC) – Release 11	PDF

1 SUMMARY

Title	Underground Cable Replacements
DNSP	Energex
Expenditure category	☐ Replacement ☒ Augmentation ☐ Connections ☒ Tools and Equipment ☐ ICT ☐ Property ☐ Fleet
Identified need	☒ Legislation ☐ Regulatory compliance ☒ Reliability ☐ CECV ☒ Safety ☐ Environment ☒ Financial ☐ Other The objective of this Business Case report is to outline the projected limitations pertaining to underground cable assets in alignment with the lifecycle management approaches specified in the Asset Management Plan. Additionally, this Business Case provides the overview of our proposed interventions, both in terms of volume and financial allocations during the regulatory period 2025-30, as informed by the results of CNAIM/CBRM modelling for cables greater than or equal to 33kV. UG cables are critical to the network due to the large energy transfer requirements without visibility of assets above the ground providing improved public safety and supply reliability - through reduced failures due to significantly less exposure to external interventions including environment and humans, in comparison to overhead network assets. However, UG construction adds much more challenges during fault location and remedial works following a failure partially negating some of the gains in 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 have a moderate quantity of older HV and LV UG cable assets. This is 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 to meet our asset management objectives. Investment in the replacement of Underground (UG) cable is required to manage legislative and regulatory compliance, and reliability, financial, safety, and environmental risks and consequences that may arise due to their failure. Through trending of defect and fault data, specific types of UG cable are being targeted for replacement.

<table>
<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>Total</th></tr>
<tr><td>$m, direct 2022-23</td><td>3.1</td><td>3.1</td><td>7.1</td><td>7</td><td>5.1</td><td>25.4</td></tr>
<tr><td>Volume (km)</td><td>5</td><td>5</td><td>5</td><td>5</td><td>20</td><td>40</td></tr>
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This investment is made up of two items listed in Attachment 5.2.01 SCS Capex model – January 2024. These are Underground Cable Replacement Business Case and Urban Cable Replacements for Olympic Impacted Areas.
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<td>Optimal Timing and NPV Analysis</td>
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For UG cable rated 33kV and above, within the framework of the Network Planning Process, an assessment is conducted for the limitations associated with each UG feeder cable. Subsequently, an individual project is initiated to ascertain 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 goal is to ensure utmost prudency and efficiency, ultimately curbing the financial impact on our valued customers and the broader community.
For a detailed case specific analysis, refer the relevant project reports.
For underground cables rated at or below 33kV, including low-voltage cables, the replacement forecast relies on historical instances of failures, defects, and known issues. Predictive modelling is not an effective approach for this asset category due to the limited availability of condition data resulting from inspection challenges and the expensive cost of diagnostic testing. Instead, a strategy based on "Safety First, As Far As is Reasonably Practicable" (SFAIRP) has been deemed the most suitable approach for managing these cables in alignment with industry best practices among Distribution Network Service Providers (DNSPs). This approach has been successfully implemented by Energex for several years, as detailed in the Asset Management Plan.
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2 PURPOSE AND SCOPE

The objective of this business case document is to define the projected limitations related to Underground cable for the regulatory period 2025-30, as informed by the results of CNAIM/CBRM modelling for >=33kV and asset performance analysis for <33kV. It is essential to read this document in conjunction with the Underground Cable Asset Management Plan.

3 BACKGROUND

Underground Cable Systems are designed and constructed to provide the physical connection and electrical continuity to allow for the safe and reliable transmission and distribution of electrical power. Failure of underground cable assets to perform their function results in negative impacts to safety, reliability, and regulatory compliance.

Energex has identified a number of current and emerging issues driving proactive replacement programs to remove high risk / condition driven UG cable from the network.

Underground cables are inherently challenging to access for maintenance or inspection. As such, verification of data to ensure reliable asset population counts, age profiling and asset condition is difficult to accurately determine in situ. Energex is working to improve its data quality and actively investigating and pursuing advancements in underground cable condition assessment, cable diagnostics and insulation rejuvenation techniques that will further assist in the management of this asset class.

3.1 Asset Population

Energex owns and maintains approximately 20,800 kms of UG cable throughout Southeast Queensland at distribution, sub-transmission, and transmission voltages. UG assets include cable accessories and UG Link Boxes, Pits and Pillars required for joints and terminations of UG cables.

Energex maintains a diverse population of underground cable types and sizes due to legacy organisation standards, changes in period contracts and advancement in cable technology.

A summary of our cable population is shown in Table 1 and Figure 1. We will have 108 km of our cable population over 50 years old, and 108km over 60 years for voltages 33 kV and above by 2029-30. Similarly, for cables below 33kV, 1,193 km will be over 50 years old, with 31km over 60 years by 2029-30. Our expected service life is 50 years for cables < 33kV and 60 years for ≥ 33kV).

Asset type	Volume (km)
< = 1 kV	13,231
> 1 kV & < = 11 kV	6,595
> 11 kV & < = 22 kV	0
> 22 kV & < = 33 kV	2041
> 33 kV & < = 66 kV	0
> 66 kV & < = 132 kV	441
> 132 kV	0
Total	**20,790**

Table 1: UG Cables Population Volume Summary

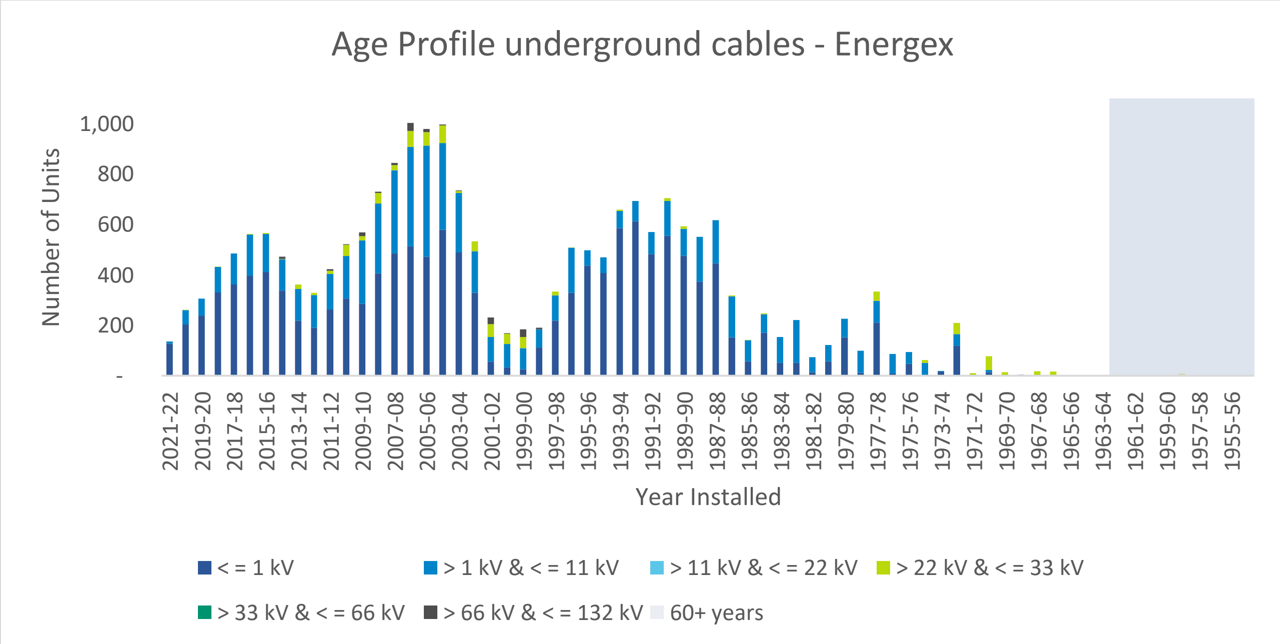

Figure 1: Age Profile Underground Cables

3.2 Distribution Cable Pits

There are 19,363 Distribution (HV and LV) Cable Pits in the Energex area. Our data systems only captured cable pits from 2001 onwards, so there is no age data available for Pits before this time. The age profile data that we do have is shown in Figure 2.

Observations from the recent introduction of Pit inspections indicate that most of our Cable Pits in the Central CBD Brisbane area need structural integrity work due to the deterioration of Pit Walls, rooves and other civil structures.

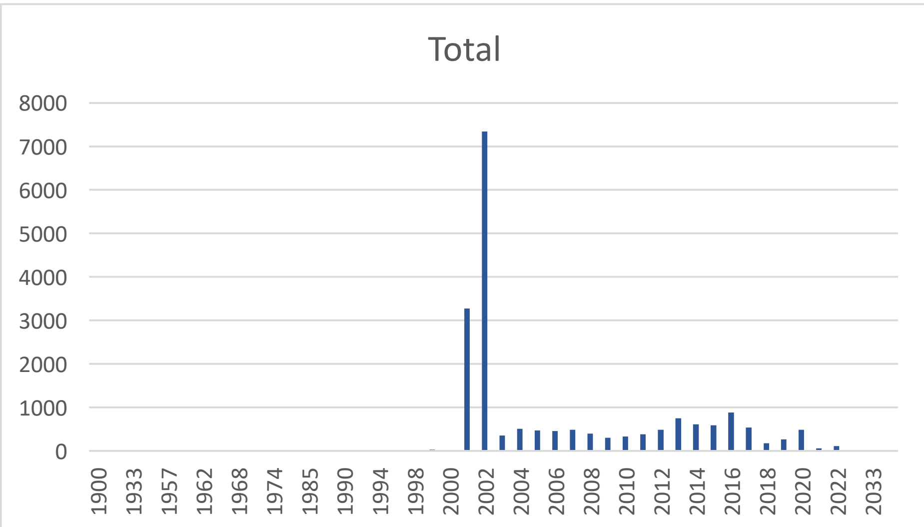

Figure 2: Underground Pits Age Profile

3.3 Asset Management Overview

This asset class is managed, consistent with our 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).

Underground cables operating at 33kV or above are managed with predictive modelling in line with CBRM/ CNAIM principles. Both observed external deterioration and measured condition data is regularly collected to be incorporated into the determination of condition scoring and Health Index for all UG cables to calculate the future probability of failure. Replacements are undertaken based on an overall risk evaluation and assessment of the consequences of failure and analysed for each UG cable to optimise the value for the community.

However, assets operating below 33kV voltage level are managed by population trends, historical failures, defects and known issues, inspected/assessed regularly where possible/practicable, and allowed to operate as close as practical to end of life before replacement. End of asset life is determined by reference to the benchmark standards defined in the Defect Classification Manual and the Maintenance Acceptability Criteria. Replacement work practices are optimised to achieve bulk replacement to minimise overall replacement cost and customer impact.

Life extension techniques are applied where practical, consistent with overall legislative, risk, reliability, and financial expectations. Problematic assets such as very high maintenance or high safety risk assets in the population are considered for early retirement.

3.4 Asset Performance

Two main failure mode has been considered in this business case as per description below:

- **Unassisted Failures:** Functional failure of an UG cable asset or component under normal operating circumstances and not caused by any external intervention such as abnormal weather or human.
- **Defects:** UG cable 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).

Unassisted asset failures occur where the programs in place to manage the assets do not identify and rectify an issue prior to the asset failing to perform its design function. Failures that are the result of circumstances beyond the reasonable control of any practical management system are deemed Assisted Failures.

Energex has developed a suite of maintenance programs to identify, prioritise and remediate underground cable asset defects where visual inspection is achievable. Defects identified via inspection programs are classified and prioritised according to the Energex Lines Defect Classification manual (LDCM).

Historical failure and defect data has been summarised in Figure 3 and Figure 4. The failure data indicates stable records with small yearly fluctuations. However, the defect data shows a moderate increasing trend demonstrating the success and effectiveness of the current condition monitoring strategy and plans in identification of more defects early to undertake proactive action and to avoid in-service failures.

Furthermore, unassisted failures in Energex show dominant failure modes of cable and terminations. Terminations and joints have traditionally shown to have higher failure rates than cables across the voltage ranges due to human factors during installation.

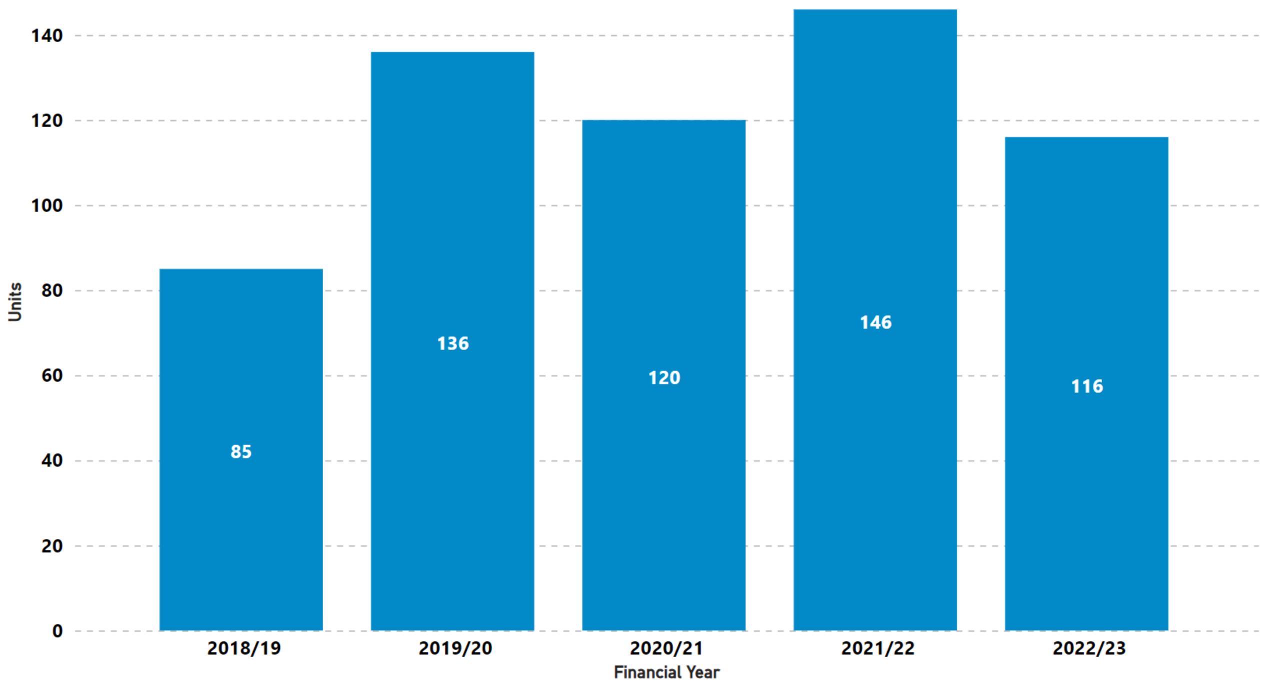

Figure 3: Unassisted Underground Cable Failures

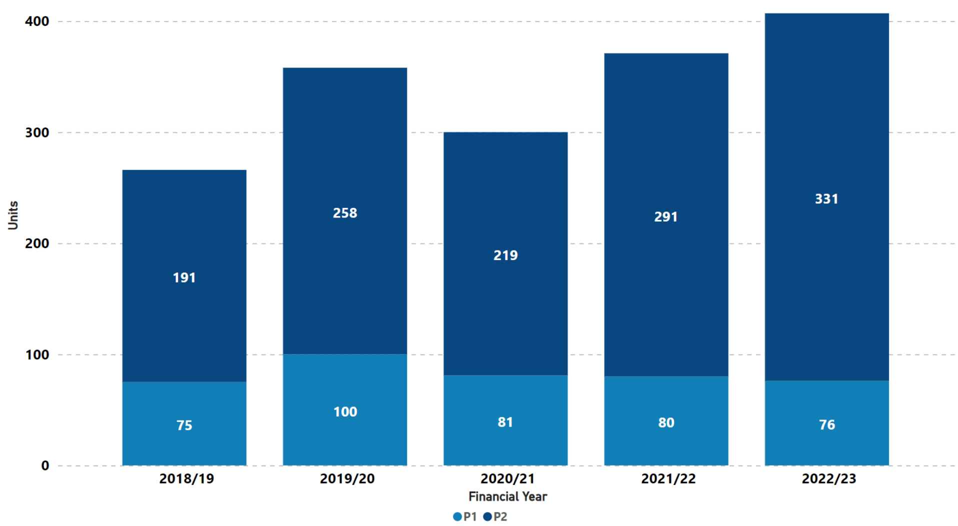

Figure 4: Underground Cable Defects

3.5 Risk Evaluation

The risk is calculated as per equation in Figure 5.

Figure 5: Monetised Risk Calculation

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 UG cables.

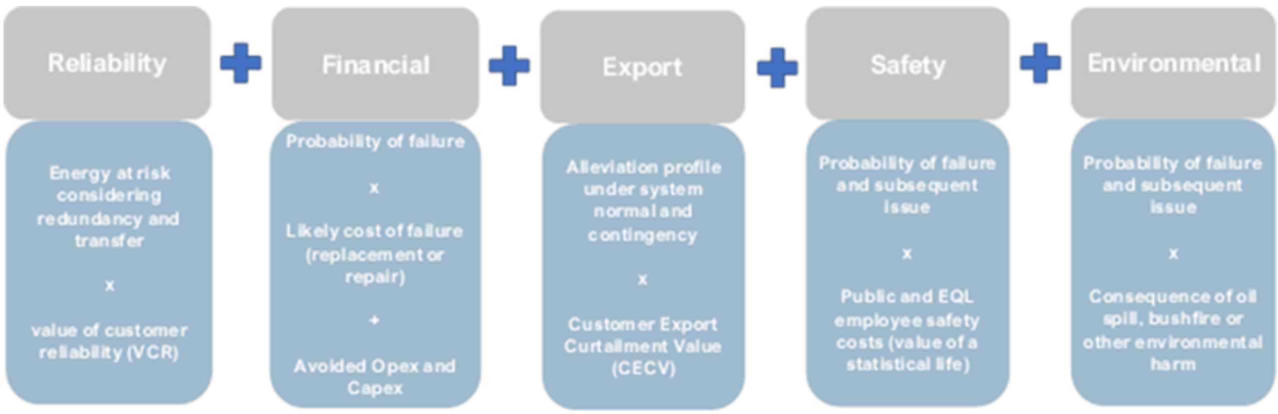

Figure 6: Total Risk Cost Calculation

3.5.1 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 and measured condition data has been incorporated into the determination of Health Index for all UG cables operating at 33kV or above voltage levels to calculate the future probability of failure.

Observed condition data mainly involves visible deteriorations of support structure and external damages to cables/terminations including rust, corrosion and leaks on metallic and fluid filled cables/terminations. Similarly, the measured condition data incorporates electrical testing results (IR, VLF and PD testing), sheath testing and thermos-scanning results.

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. The equation involves two specific constant factors to be applied aligning the PoF with a specific type of asset and historical failure data experienced by the DNSP operating in different operating conditions. Please refer to the CBRM/CNAIM document for full details about these constants and PoF/HI relationship equation.

Considering the overall low failure rate and reliability consequences of failures, the condition data (observed and measured) process is considered uneconomical for UG cables assets below 33 kV voltage level.

3.5.2 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 an UG cable. 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 UG cable, as well as replacing the cable under emergency. The unplanned cost could vary significantly from couple of thousands to hundreds of thousands depending on length of the cable, location of the cable, type of the fault and the damage occurred to the cable or associated components such as termination/termination box, cable support structures, cable joint etc.
- **Safety:** There is a risk of multiple serious injuries or fatality following a failure of an UG cable, specifically old assets with metallic termination housings (potheads, link boxes etc), dependent on the failure mode and proximity of the employee/contractor during the event. Considering that these termination boxes are installed in public area a public member could be involved specifically near school or high pedestrian areas.
- **Environmental:** There is a moderate risk of environmental impact/contamination under right conditions in case of failure of an UG cable specifically fluid filled cables/boxes/terminations.

3.5.3 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

The identified need for this investment is driven by a positive cost/benefit analysis based on Value of Customer Reliability, Financial, Safety and Environmental benefits.

Key current issues associated with this asset class and driving replacement programs are:

- Cast iron potheads.
- Low voltage Concentric Neutral Solid Aluminium Conductor (CONSAC) cable
- Hochstadter Screened Separately Lead Sheathed (HSL) cable.

Key emerging issues associated with this asset class and driving replacement programs are:

- Water treeing in XLPE cable

- Ageing cable and associated obsolescence issues
- Cable jointing skill and capability
- Submarine cables
- Cable joint and termination failure rates
- Recovery of redundant cable
- LV Pillar defect and failure rates
- Distribution Cable Pit Lids not designed for explosive failures
- Distribution Cable Pits with structural defects requiring pit rebuilds
- Distribution Cable Pits with various defects requiring rectification work
- Unreliable distribution cable and supply configurations feeding future critical Olympic venues.

Our Asset Management Plan – Underground Cables outlines each of these issues and their impact on future replacement programs.

4.2 Compliance

The Electrical Safety Act 2002 (Qld) s29 imposes a specific duty of care upon Energex, which are prescribed Electrical Entities:

1) An electricity entity has a duty to ensure that its works
   a) are electrically safe
   b) are operated in a way that is electrically safe.
2) Without limiting subsection (1), the duty includes the requirement that the electricity entity inspect, test and maintain the works.

Energex, under the Electricity Safety Regulations 2013 (Qld), is required to notify the Electrical Safety Office in the occurrence of any Serious Electrical Incident (SEI) or Dangerous Electrical Event (DEE).

Under the Electricity Regulation 2006 (Qld) an electricity entity must, in accordance with recognised practice in the electricity industry, periodically inspect and maintain its works to ensure the works remain in good working order and condition.

The Queensland Coastal Protection and Management Act controls infrastructure on and across tidal lands, waterways and harbours. The Transport Infrastructure Act 1994 (Qld) (specifically Division 3) covers assets within carriage way boundary of all state roads.

The Marine Parks Act 1982 (Moreton Bay areas) covers infrastructure such as cables to Russell Island and Bribie Island

5 ASSET LIMITATION FORECAST SUMMARY

5.1 Asset Condition Limitations – Health Index (HI) Summary

Energex uses CBRM/CNAIM principles to predict the end of life of UG cables operating at 33kV or above voltages. CBRM uses age, location, 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 7.

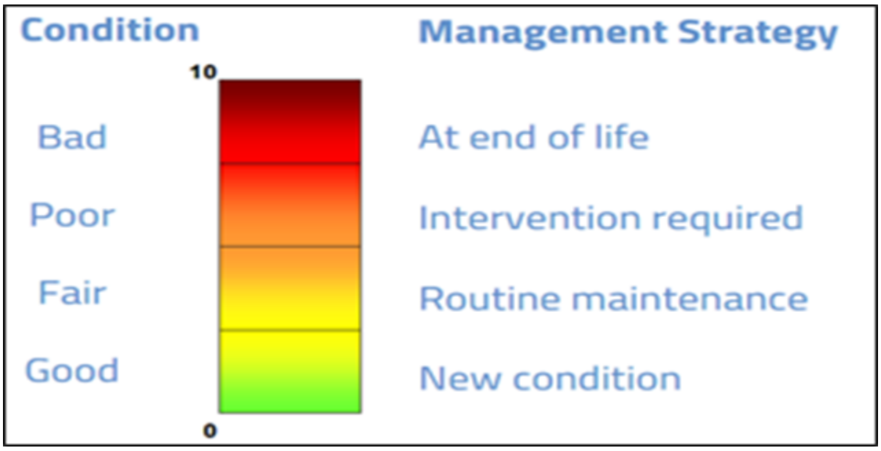

Figure 7: Health Index and Condition Relationship

The latest HI information of underground cables has been provided in Figure 8. A HI of 7.5 indicates poor condition of the cable with intervention required in a specified time frame. Figure 8 also illustrates that approximately 42 km of underground cables are currently assessed with HI of over 7.5 requiring intervention in next few years.

Additionally, estimated forecast HI summary of UG cables at the end of the modelling period (year 2030), as per CBRM, is provided in Figure 9, indicating 60 km of underground cables exceeding the HI of 7.5. The remaining UG cable asset fleet operating below 33kV including all LV cables, which constitutes more than 90% of total cable volumes, are required to be replaced additionally. The proposed replacement volumes for this lower voltage cable category are based on historical failures rates, number of defects and known issues. A total of 60km of UG cables replacements is forecast for the regulatory period 2025-30.

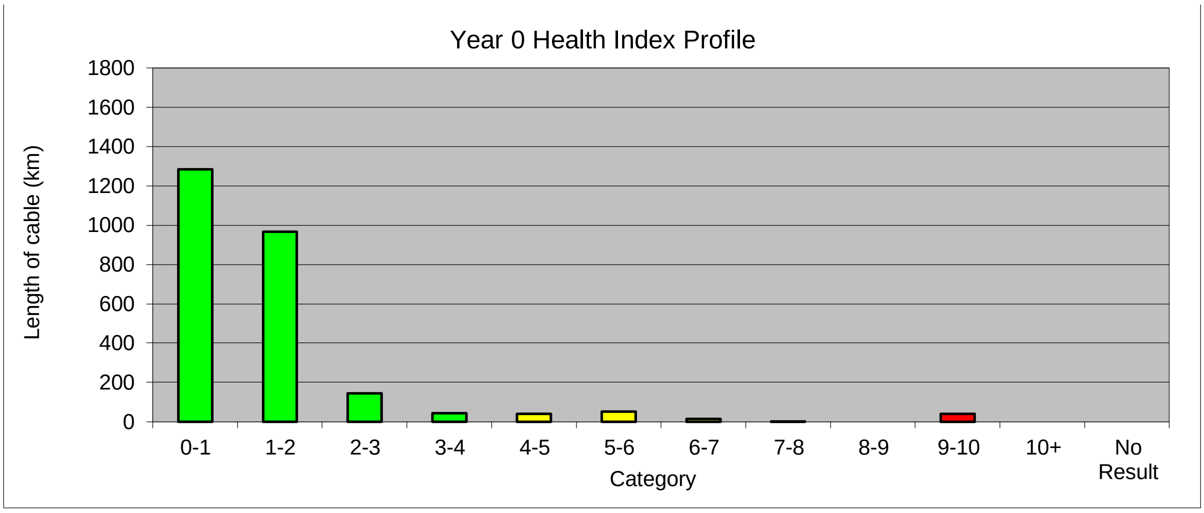

Figure 8: Current HI Summary

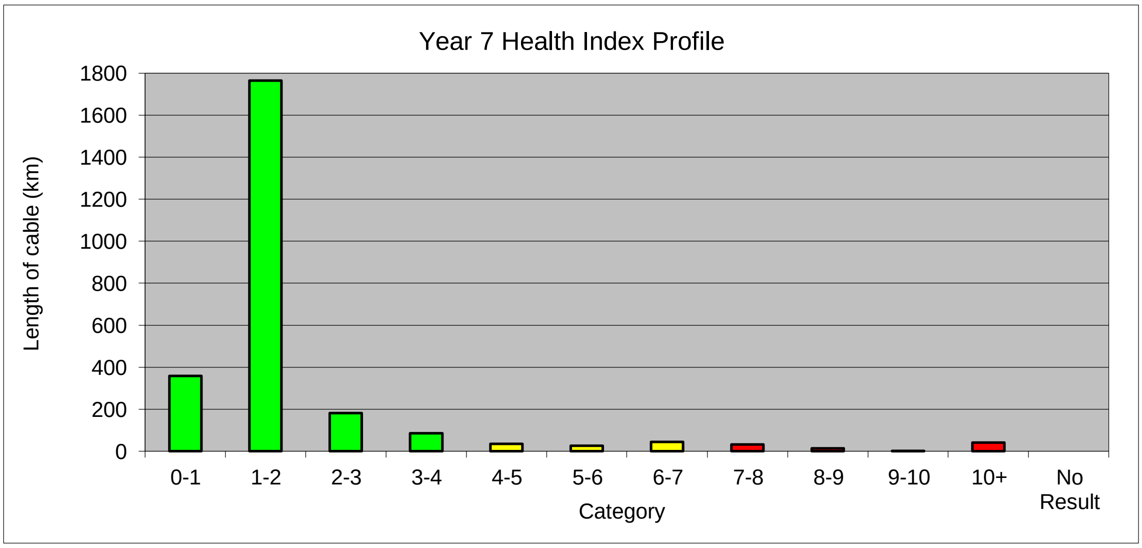

Figure 9: Future Year 7 Forecast HI Summary

6 OPTIMAL TIMING AND NPV ANALYSIS

This business case presents asset limitations in terms of asset condition, health index and associated monetised risk values based on CNAIM/CBRM modelling outcomes incorporating the historical data so far, as per descriptions in Section 5. This business case also forecasts intervention requirements for this asset class during the regulatory period 2025-30.

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 project, based on overall prudency and efficiency to minimise the cost impact on customers/community.

6.1 Asset Replacement Limitation Forecast

Based on CNAIM/CBRM model and historical performance, the required replacement volume for 2025-30 is 60km in total as outlined in Table 2.

Year	2025/26	2026/27	2027/28	2028/29	2029/30	Total
Volume (km)	12	12	12	12	12	**60**

Table 2: UG Cables Replacement Volumes

After conducting the risk evaluation, optimal timing and NPV analysis for individual project to optimise the cost/benefits for community the proposed modified volume summary and expenditures have been provided in Table 3.

Year	2025/26	2026/27	2027/28	2028/29	2029/30	Total
$m, direct 2022-23	3.1	3.1	7.1	7	5.1	**25.4**
Quantity	5	5	5	5	20	**40**

Table 3: UG Cables Replacement Volumes Summary – RIN Forecast

7 RECOMMENDATION

The proposed volume provides the best balance of benefits and risks for the organization and continues our existing asset management strategy.