Underground Cables Investment Case

Underground (UG) Cables carry load and fault current safely and reliably, without overheating or causing damage to the environment, across all voltage levels of the network. They are a linear asset providing connection between all points on Essential Energy's distribution network, from its zone substations through to the interface with customers and transmission service providers. They are used as an alternative to overhead conductors.

Scope

This investment case addresses UG Cables and their terminations including ST, HV, LV, and Service cables both inside and outside zone substation boundaries. It addresses only Essential Energy's assets, and not those of its customers as defined by the NSW Service and Installation Rules.

The investment is required to meet the capital expenditure objectives (NER 6.5.7) for quality, reliability and security of electricity supply and to meet regulatory and legislative obligations for Standard Control Services.

Underground System Assets

- Cable
  - Subtransmission (ST)
  - High Voltage (HV)
  - Low Voltage (LV)
  - Service
  - Streetlight
- Joint
- Termination

Forecast $FY24

The UG Cables forecast accounts for 4.63% of the total Repex portfolio for FY25 to FY29.

FY25	FY26	FY27	FY28	FY29
$9.9M	$10.1M	$10.4M	$10.6M	$10.9M

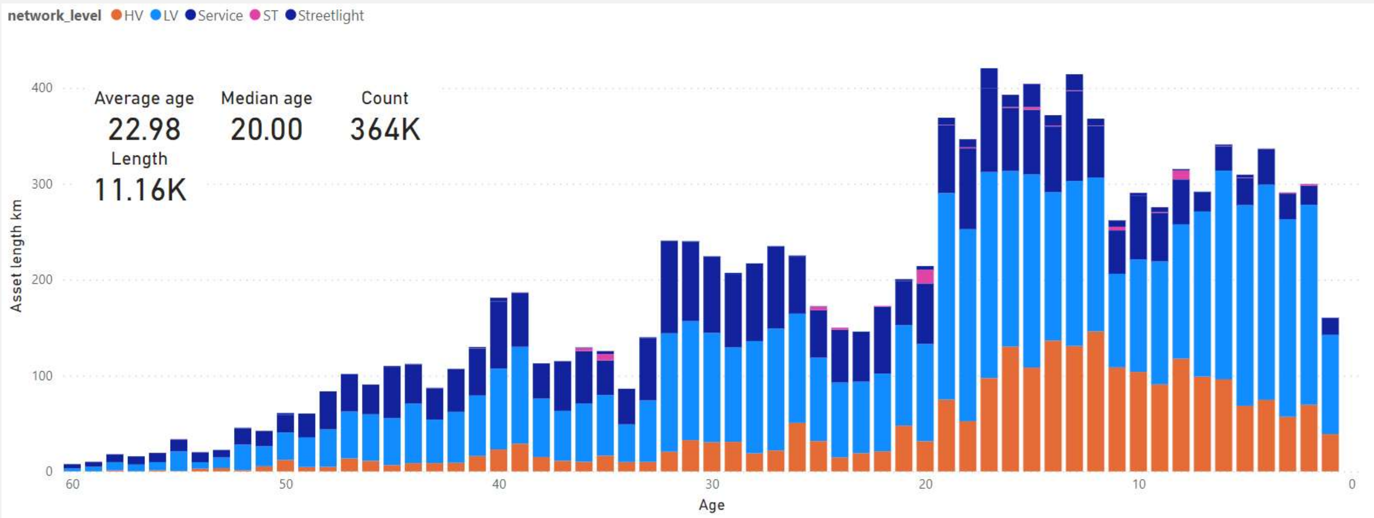
Asset Health/Profile

Asset Profile

Essential Energy's network includes approximately 364,000 UG Cable assets recorded in Smallworld, across a length of 11,000km. Assets at higher voltage levels typically have longer and straighter runs than those at lower voltage levels, and hence have fewer joints per km. Most cables are aluminium core with cross-linked polyethylene (XLPE) insulation however, a variety of construction types are present on the network.

Insulation	Count	Length (km)
XLPE	134,412	6,940
UG Service	199,052	3,156
CONSAC	8,357	321
Paper lead (PLY)	3,203	317
PVC	10,080	248
Other	8,489	175
Total	**363,593**	**11,157**

The Age Profile of the Underground Cable assets is shown in the following figure.
Due to the combination of asset volumes, failure modes, and replacement costs, asset age has been used as a proxy for asset health.



Risk Analysis

This risk section provides an overview of the UG Cables risk model. It is supported by documents and **6.03.02 Network Risk Management Manual, 6.03.03 Appraisal Value Framework and 6.03.04 System Capital Risk and Value Based Investment** methodology.

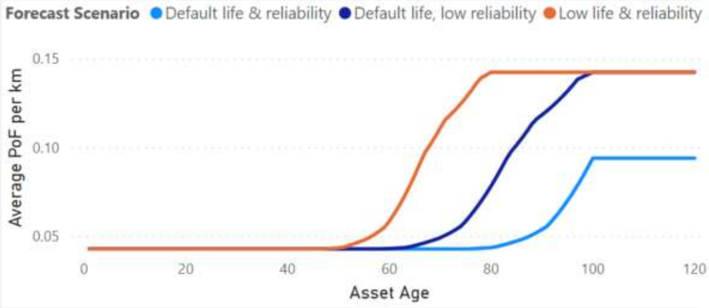
Probability of Failure (PoF)

Failure modes for UG Cables have followed the guidance in the DNO Common Network Asset Indices Methodology (OFGEM), focusing on those failure modes which result in power outage on the network. Failures include those which occur in the cable itself, joints, and terminations. Detail on the development, calibration, and assumptions in the PoF Model are captured on Page 6. The resulting OFGEM input parameters for different network levels and scenarios are shown below. Notably for this analysis all network levels are modelled with identical OFGEM input parameters, with the variation between scenarios providing confidence bounds to account for any true asset variability.

OFGEM input parameters by network level and scenario

Network level	Normal Life (default)	Normal Life (low)	Reliability Factor (default)	Reliability Factor (low)
ST	100	80	1.0	1.5
HV	100	80	1.0	1.5
LV	100	80	1.0	1.5
Service	100	80	1.0	1.5
Streetlight	100	80	1.0	1.5

Average PoF per km by Asset Age and Forecast Scenario



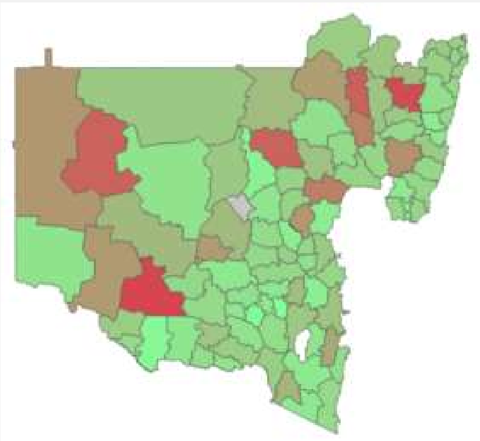
Consequence of Failure

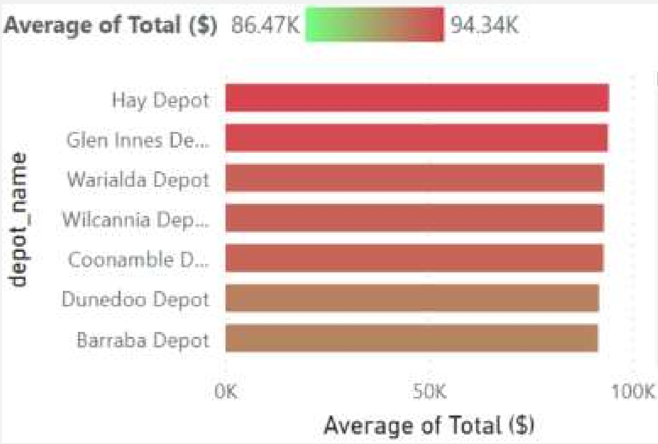
The consequence of failure for an UG Cable asset describes the impact of a functional failure.
Consequences have been evaluated using 6.03.03 Appraisal Value Framework.
Consequence costs are dominated by Safety costs.
UG Cable assets have a calculated safety fatality risk conforming with the Tolerable range from 6.03.02 Network Risk Management.

Component	Average ($ per asset)	Median ($ per asset)	Total ($ billion)
Network	4,599.84	1,797.81	1.358
Financial	920.20	920.69	0.272
Safety	82,478.55	82,941.07	24.343
Bushfire	128.63	20.35	0.038

Totals show the consequence cost should the entire UG Cable fleet fail once per asset.

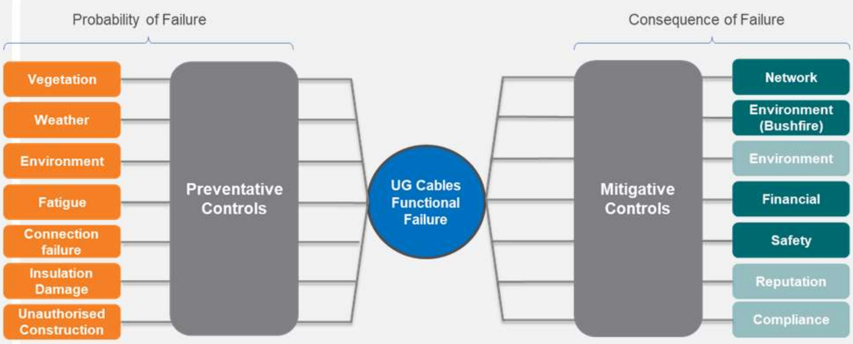
The images below display a **summary of asset criticality** (quantified by the average of total consequence per asset failure) for UG Cables by depot. The range of average criticality between depots is low.





Network Risk

Asset risk is a function of the probability of failure and the consequence of failure. The risk model has been developed using the Asset Risk Management Framework, and represents the relationship between the primary drivers behind UG Cables functional failures and the components used to determine the consequence of failure.



Forecasting Approach

The replacement Capex forecast (FY25-FY29) has been calculated using Essential Energy's optimisation software (Copperleaf) which uses a risk based methodology to maximise the value of the investment portfolio within constraints established by Essential Energy that are consistent with our Corporate Risk Framework, Asset Management System, applicable standards, rules, regulations and licence conditions. To assure efficiency our portfolio has been constrained to meet customer and stakeholder expectations.

In line with NER capital objectives, the objectives of our total replacement portfolio have been informed through extensive stakeholder engagement and consist of:

- Maintain reliability performance (network risk)
- Long term reduction of bushfire start risk by 20% over 20 years (2.5% FY25-29)
- Maintain safety performance

The replacement quantities of UG Cables consist of the sum of:

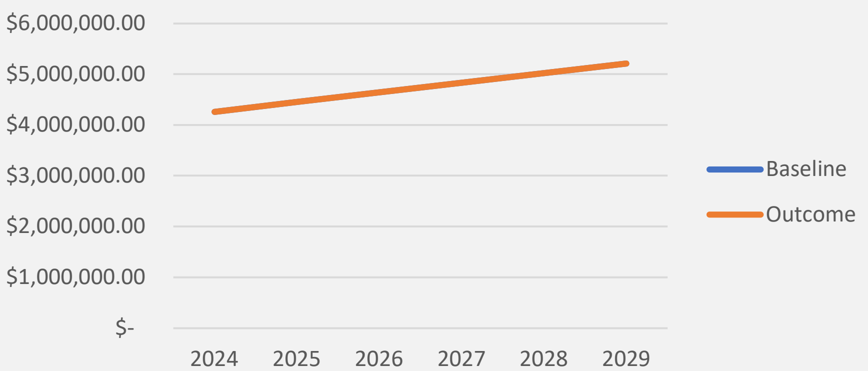
1) Forecast functional failures of assets based on analysis of historical asset performance, and incorporating insights from the ongoing development of probabilistic models, with interventions that include a mix of cable repairs, and replacement of entire segments where justified; and
2) CONSAC cable failures have been forecast to replace the entire cable segment by XPLE **to maintain overall network risk values within defined objectives.**
3) Ungrounding of high risk areas as identified in the separate business case **Attachment 10.06.02** .

The probabilistic method has been tested and validated against historic volumes to ensure that it is accurate at the population level.
The above asset interventions utilise a probabilistic approach that has been developed through detailed analysis of historical asset performance to scale OFGEM parameters.
Forecast investment expenditure has been determined by multiplying the forecast replacement quantities of UG Cables assets by applicable unit rates.

Refer to **6.03.04 System Capital Risk and Value Based Investment** methodology for details on the **portfolio** wide optimisation planning approach and risk outcomes, and **10.01.04 Capital Unit Rates** for unit rates.

Optimised Portfolio Outcomes

Risk Trend (2024-29 Optimised portfolio)
Currently there is no proactive replacement expenditure in the forecast for UG cables resulting in minimal change between baseline and outcome for this asset class, as shown in the graph below. Forecasted expenditure is to repair failed cables and replace segments of cable after cable faults have occurred.



Asset Grouping

- Grouping of the asset population was not required for forecasting purposes

Resilience-related expenditure
A separate Investment Case (**Attachment 10.06.02**) has been submitted for Resilience spend to underground 40km of high risk locations during the 24-29 period, taking into account the impact of climate change.

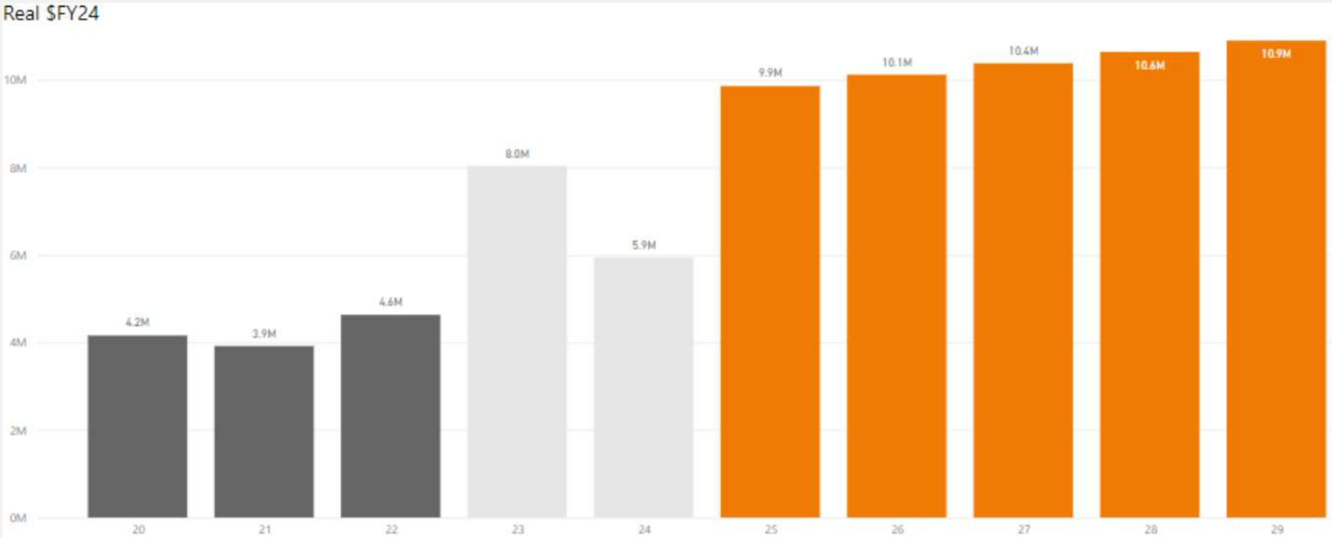
Options

1. UG Cables replacement expenditure has been modelled on a replace with like-for–like, except for legacy material, such as CONSAC cables, in which case replace with XPLE.

- Non-network solutions are considered when planning the replacement of a specific asset.
- Value calculators determine the most prudent and efficient investment choice available at the time for a specific project. For example, options include: replace with overhead network, replacement of elements with different types or materials; or replacement of a segment by a non-network solution.

10 Year Replacement Capex Forecast

Forecast replacement expenditure for UG Cable across the 2024-29 period is $51.9M, averaging $10.4M per annum. Actual and projected expenditure for the remainder of the 19-24 period is $26.7M.



Data source: Actuals: Internal delivery reports, Forecasts: Copperleaf
Note: All values are in FY2023-24 real dollar terms

Justification

We are confident that our approach delivers an efficient and prudent level of investment as:

- **Clear drivers from Asset Management Objectives** for Reliability, Quality, Safety and Compliance (as detailed in **Attachment 10.01 Strategic Asset Management Plan**).
- **Review and moderation:** Our forecasts have been tested and reviewed by our executive management and the Board, subject to top-down challenges (as detailed in **6.03.04 System Capital Risk and Value Based Investment**) and the forecasts moderated based on feedback and discussion.
- **Critical Environmental Factors:** Risk associated with aging UG Cables and exposure to flooding.
- **Customer needs:** Through customer engagement, refer Chapter 4 of our Regulatory Proposal, customers indicated a desire to maintain current levels of safety and reliability, and increase expenditure for resilience based projects. This investment will contribute to maintaining safety and reliability, within the wider Repex portfolio as well as proactive Resilience projects.

The major benefits from the proposed UG Cables investments (against the **change nothing** scenario) are:

- **Improved reliability and reduction in fault and emergency costs:** Maintaining the health of UG cables through optimisation of investments will allow us to maintain suitable reliability for our customers. By replacing CONSAC cable segments with XLPE when there is a failure – noting that CONSAC cables represent ~5% of the asset class but account for ~40% of cable failures – will improve reliability for customers served via those segments and over time will lead to a reduction in the number of fault and emergency call outs and associated costs per unit of installed cable.

Forecast UG Cables Repex expenditure for the 2024-29 period is $51.9M. The increase from 2019-24 actual/forecast of $26.7M is due to:

- Increased replacement of aging CONSAC cables
- Additional 40km undergrounded for Resilience projects of $18.3M – Refer to **10.06.02 Resilience Undergrounding High Risk Locations Investment Case**

Key Assumptions

- **Attribution of failures to specific assets** was not possible. Tasks are raised against a variety of assets including cubicles and substation sites, which can have many associated UG cable assets that are not able to be distinguished from each other. The need to approximate an age at task date for interventions was limited by use of OFGEM modelling approach (which focussed on the number of failures rather than the age they occurred).
- **Population data used in analysis** required cleaning prior to use. Assets installed prior to 1961 or with invalid installation dates were excluded from analysis. Of the assets analysed, conductor material and insulation were often either missing or had conflicting attributes in different fields. The conductor material and insulation used in analysis was constructed by applying a hierarchy to relevant fields and cycling through until a field presented a valid attribute. This included cable's Common Name, Construction Type, Operating Voltage, and Date Installed.
- **Development of OFGEM model** required some adaptation for this asset population. In its strict interpretation, OFGEM only specifies outcomes for cables which are > 33kV.The OFGEM analysis uses asset constants specified for higher voltage cables and is calibrated as described below.
- **Calibration of OFGEM Parameters** was achieved by comparing failures predicted in 2020 by a given set of OFGEM parameters to historical failures recorded between 2015-2019.
- **Consequence models** were developed in accordance with 6.03.03 Appraisal Value Framework

Strategic Direction	We shall		
Acquisition	**Selection Criteria** *Continue* to select new cables in accordance with CEOM7098 and CEOM7004. This includes the use of XLPE insulation and a choice of conductor material, cross-sectional area, and number of cores which matches the application. *Continue* to utilise and review installation practices (i.e. spare ducted) which promote maximum lifecycle value. (CEOM7804) *Continue* to procure joint and termination kits in accordance with CEOM7004. Continue to require correct joints and terminations to be chosen for the particular type of cable at the site.	**Procurement** *Trial in the short term* VLF testing on commissioning and at ASP handover, to provide inputs to a maintenance regime business case. *Enhance* maturity over ASP quality control governance, (CEOF2568). *Continue* to share responsibility with ASPs for the quality of procured assets to be installed on the network in accordance with CEOM7004. *Investigate in the medium term* opportunities to further drive standardisation of installed cable types, including through enhanced governance over compliance to CEOM7004.	
Ops & Maintenance	**Preventative Maintenance (Testing & Inspections):** *Continue* 6-yearly inspection and testing of zone substation ST cables, and in the short term continue opportunistic inspection of cable terminations in kiosks as per CEOP2474. *Investigate in the short term* testing and inspection synergies with other UG system assets, such as simultaneous VLF testing through UG switchgear and cables. *Develop* a maintenance regime and associated business case for management of UG Cable assets, including health monitoring appropriate to the level of risk and a review of relevant maintenance practices across DNSPs.	**Preventative Maintenance (continued):** *Trial in the short term* VLF testing on other HV cables where there is value, to provide inputs to a maintenance regime business case. Triggers may include on-repair, or periodic testing for cables which have high criticality or a history of faults. **Corrective and Breakdown Maintenance:** *Trial in the short term* VLF testing of cable sub-sections either side of a fault during breakdown maintenance, to provide inputs to a maintenance regime business case.	
Interventions	**Serviceability** *Develop in the medium term* an UG assets maintenance manual which specifies serviceability limits linked to testing outcomes as a trigger for asset interventions.	**Prioritisation** *Continue* to prioritise defect resolution of UG Cables by severity and risk.	
Interventions	**Repairs** *Continue* to assess appropriate repairs through trade-off between extended working life, the cost of that life extension, and risk as outlined in CEOM7804. *Maintain* a long term approach to progressively replace high safety risk terminations (i.e. porcelain and pot heads).	**Replacements** *Implement* criteria for the use of cable replacement rather than repair as an intervention option. This should be linked with testing and associated serviceability thresholds.	
Disposals	**Individual Assets or Entire Asset Variants** *Continue* to dispose of assets in accordance with CEOP8074. Where legacy asset variants are retired, ensure support systems and data are appropriately managed out of service.	**Hazardous Materials** *Continue* to manage hazardous materials in accordance with CECM1000.10.	
Asset Support	**Process & Information** **Zone substation and ST cables:** • *Develop in the medium term* a business case to support CAPEX associated with technology uplift in testing, such as augmentation of VLF machines to enable PD testing. • *Investigate in the medium term* opportunities for capability uplift in asset health analysis through VLF graph comparison capability (in-house or vendor software) for degradation and remaining life estimation. **All cables:** • *Create* individual records for UG Cable assets in the EAM system, so that asset health can be monitored and work tasks can be raised against assets directly. • *Refine* capability and documentation regarding commercial tendering of cable replacement (to drive reduction in $/m).	**People & Training** *Introduce in the medium term* training for a limited number of inspectors in the use of VLF testing equipment (in combination with expansion of testing program). *Enhance* training for dedicated underground staff regarding signs of poor asset health during ASP acceptance checks and regular network inspections. *Continue* to refine education around the impacts of moisture ingress on cable life and associated mitigation techniques.	