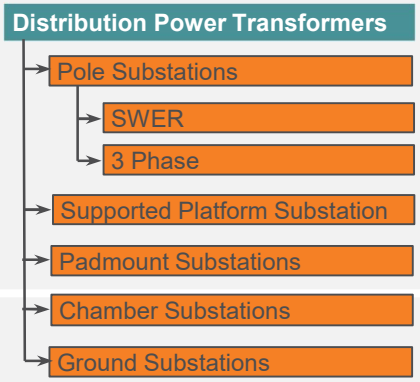
Distribution Power Transformers Investment Case

Distribution power transformers (also known as substations) convert the higher voltages suitable for distribution, into low voltages suitable for use by consumers and their equipment.

Scope

This investment cases addresses Distribution Power Transformer (DPT) assets located on poles, in enclosed substations, in chamber substations and within a fenced area on the ground and also includes sub-assemblies of windings, tank, bushings and off load tap changers.

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.



Forecast $FY24

The Distribution Power Transformer forecast accounts for **4.49%** of the total Repex portfolio for FY25 to FY29.

FY25	FY26	FY27	FY28	FY29
$8.7M	$11.7M	$14.8M	$11.2M	$16.4M

Asset Profile/Health

Asset Profile

Essential Energy's network includes approximately 140,000 in service DPT assets recorded either directly or implicitly through association with poles, chamber substation, enclosed substations, ground substations, or zone substation sites. Such implicit assets were assumed to have the same age as their explicit site.

Sub Construction Type	(Blank)	<100	100<x<500	500<x<1000	>1000	Total
2 Pole Platform Substation	0	5	0	18	6	82
Chamber Substation	0	3	53	75	253	368
Ground Substation	3	1	37	41	99	154
Pad/Kiosk Substation	5	236	10	2,123	1,177	6,827
Pole Substation	232	114,249	3,285	1,336	13	132,342
Supported Platform Substation	1	6	16,512	60	5	296
Unknown	18	1	224	0	1	20
Total	**259**	**114,501**	**20,122**	**3,653**	**1,554**	**140,089**

Due to the combination of asset volumes, failure modes, and replacement costs, asset age has been used as a proxy for asset health for this asset class.

This risk section provides an overview of the Distribution Power Transformer 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

Failure modes for Distribution Power Transformers have been identified through a Failure Mode Effects Analysis (FMEA) with subsequent analysis focusing only on those failure modes with asset life ending consequence. The parameters have been applied by Voltage and kVA, reflective of the design and stresses on the asset. Detail on the development and assumptions in the PoF Model are captured on Page 6. The generalised Weibull parameters are shown below.

Analysis of the asset data from 2006 – 2021 identified 9,136 asset failures. The Failure Database with improved data quality identifies a significant portion of the failures are attributable to Lightning. This is an assisted failure and has been included to appropriately model the baseline risk. This introduces a random failure mode to the conventional aging failure modes. Due to the random nature of the assisted failure mode, preventative replacements are influenced more by the consequence. To capture each of the failure modes in a single set of parameters has resulted in a higher characteristic age than similar aging assets. This combined with a lower shape parameter contributes greater risk throughout the early and mid-life. Weibull parameters used in the risk model are shown below.

Distribution 100-500kVA: **shape (β) = 2.4 , characteristic age (α) = 98.4**

Remaining Transformers: **shape (β) = 2.1 , characteristic age (α) = 116.1**

Consequence of Failure

The consequence of failure for a Distribution Power Transformers asset describes the impact of a functional failure.

Consequences have been evaluated using the **6.03.03 Appraisal Value Framework.**

Consequence costs are dominated by Network and Financial costs.

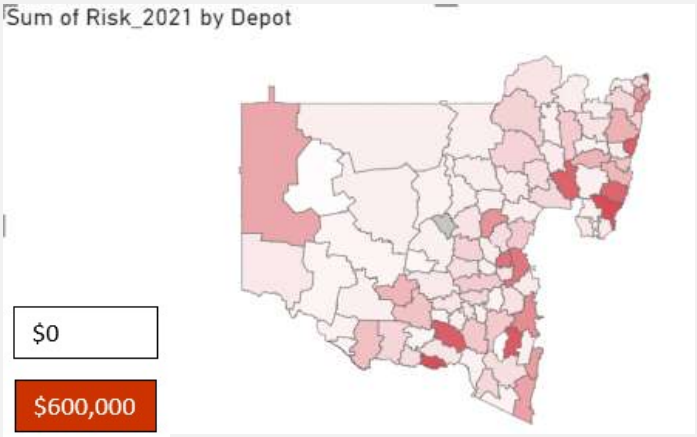
Every individual asset has a calculated safety fatality rate conforming with the broadly acceptable criteria as per **Network Risk Management Manual (6.03.02)**.

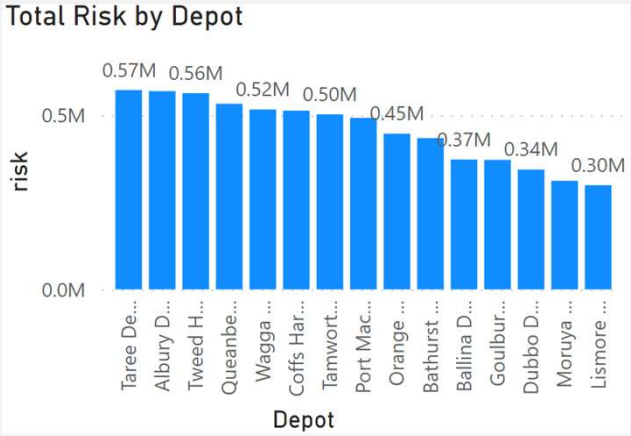
Component	Consequence		
	Total ($ million)	Average($)	Median($)
Safety	$86.7	$619	$619
Network	$2,187.6	$15,616	$1,589
Bushfire	$67.9	$485	$478
Environment	$0.4	$3	$3
Financial	$1,229	$8773	$5608

Totals show the consequence cost should the entire fleet fail.

Risk Model

Asset risk is a function of the probability of failure and the consequence of failure. The images below display a **summary of asset Risk** (quantified by the total Risk per Depot) for DPT by depot.





Risk Model Calibration

The asset risk has been calibrated against top-down performance figures.

The table to the right shows the difference or delta between the risk model output and the monetised performance, the scaling factors applied, and key commentary describing the delta for each value measure.

Value Measure	Safety	Network	Bushfire	Financial	Total
Unscaled Model Outputs	$0.3M	$8.9M	$0.2M	$4.6M	$14.0M
Top-Down Performance	$0.33M	$7.88M	$0.7M	$0.98M	$9.27M

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

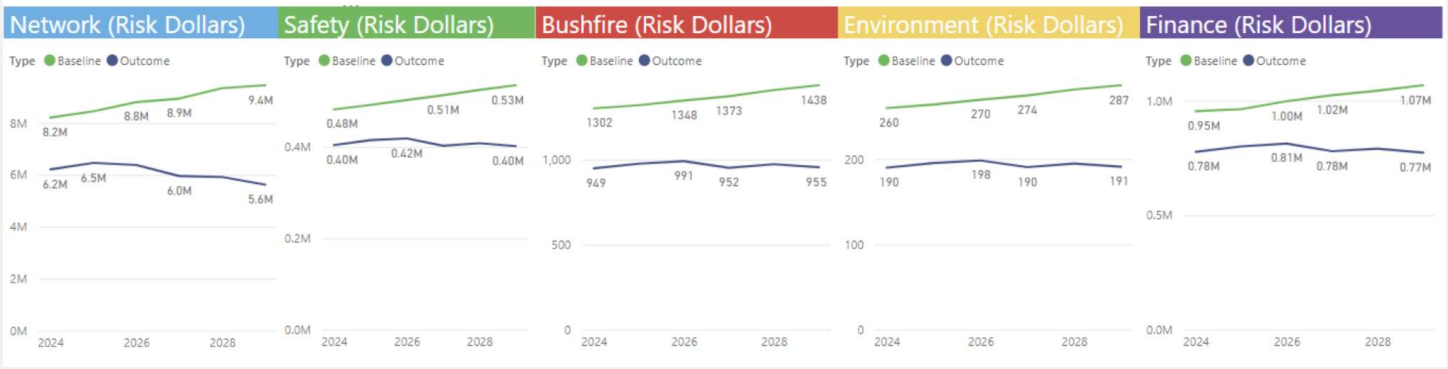
The replacement quantities of Distribution Power Transformer consist of the sum of:

1. Forecast **conditional replacement** volumes
2. Optimised **risk-based replacements to maintain overall network risk values within defined objectives.**

The above asset interventions utilise a probabilistic approach that has been developed through detailed analysis of historical asset performance to establish Weibull parameters (refer 6.03.03.17).
The probabilistic method has been tested and validated against historical volumes to ensure that it is accurate at the population level.
Forecast investment expenditure has been determined by multiplying the forecast replacement quantities of Distribution Power Transformer 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 Outcome

Risk Trend (2024-29 Optimised portfolio)
Over the 5 year regulatory window, total **baseline** monetised risk due to **functional** DPT failure is estimated to increase to $11M by 2030. The figure below depicts the **baseline** scenario and investment **outcomes** ($6.8M) of the optimised program for DPT.



Asset Grouping

Distribution Power Transformer assets have been grouped into two categories for investment optimisation purposes according to the different modes of replacement:

1. **Conditional** replacement - where an inspection has identified a defect that must be rectified in a predetermined timeframe by asset replacement;
2. **Risk-based** replacement - e.g. The risk attributed to an asset through its combination of probability of failure and consequence of failure is high and replacement is the prudent action to reduce this risk. Assets within this risk-based replacement group have been included in the optimisation process where they will have reached Equivalent Annualised Cost (EAC) positive by FY34.

- 6,985 asset groups were loaded into 312 investments in Copperleaf to provide flexibility in portfolio optimisation.

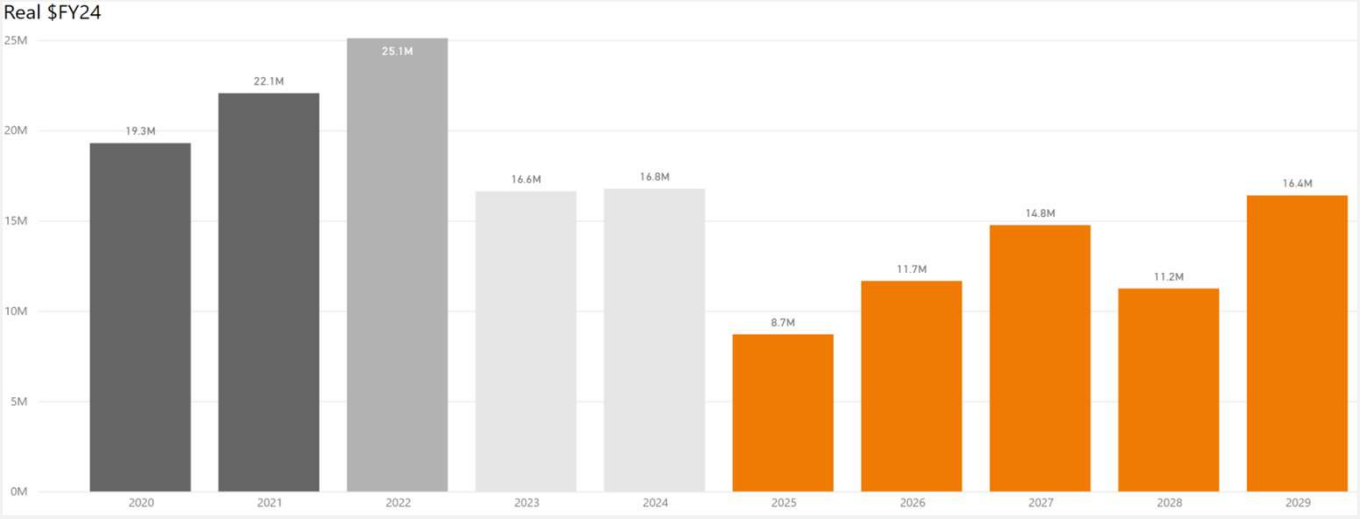
Options

1. DPT replacement expenditure has been modelled on a replace with like-for–like replacements.
2. Risk based asset groupings are treated as additional optional investments for consideration in the total optimised portfolio to meet overall portfolio objectives.

- 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: like-for-like replacement; or replacement by less expensive equipment. Retirement of the asset, feeder or zone substation may be considered if load and network constraints permit.

10 Year Replacement Capex Forecast

Forecast replacement expenditure for Distribution Power Transformer across the 2024-29 period is $62.8M, averaging $12.6M per annum. Actual and projected expenditure for the remainder of the 19-24 period is $99.9M.



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**).
- **NER Capex Objectives:** form the basis of our proposal
- **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:** There is increased risk associated with Distribution Power Transformer due to factors such as oil containment and public access.
- **Customer needs:** Through customer engagement, refer Chapter 4 of our Regulatory Proposal, customers indicated a desire to maintain current levels of safety and reliability. The investment will contribute to maintaining safety and reliability, within the wider Repex portfolio.

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

- **Improved network risk and maintainability**: Investment in this asset class will reduce network risk through replacement of Distribution Power Transformer of degraded condition and/or in high risk locations with more resilient materials of acceptable condition; and
- **Maintain levels of service for our customers:** Maintaining the health of assets through addressing locations of highest risk, will result in fewer unplanned failures from asset degradation and therefore will enable us to maintain service reliability for customers.

Forecast Distribution Power Transformer Repex expenditure for the 2024-29 period is $62.8M. The reduction from 2019-24 actual/forecast of $99.9M is due to:

- Reduced volume of replacements due to portfolio risk targets.
- Change in reporting with costs being captured differently for this asset class (i.e. expenditure related to HV RMUs and LV switchboards)

Key Assumptions

- **Attribution of Asset Age to Task** – task is raised against the Substation Site while the Age is attributed to the "Tracked Asset" transformer asset. The relationship between Site and Tracked Asset is broken when the asset is replaced, a Moved Asset table maps the movements of the Tracked Assets. The Moved Asset table was used as the primary table to identify a replacement and a task against the previous Site was joined if available in the prior 3 months. Movements without Tasks joined were not included in the probability of failure as the driver was uncertain. **Categorisation of task maintenance activity** was performed in a task code mapping spreadsheet. Replace tasks were categorised based off their task group, task description, and cause description.
- **Weibull Parameters** developed by curve fitting in Power BI. The population was subdivided by voltage level & kVA.
- **Calibration of Weibull Parameters** was achieved by comparing failures predicted for a given set of Weibull parameters to historical failures recorded in the Network Failure Database between 2016-2019.
  Consequence models were developed in accordance with 6.03.03 Appraisal Value Framework
- **Conditional replacements** are applied in each preventative scenario. The conditional replacements are defective units that are identified through asset inspections. Risk-valued work will attribute the correct rectification period to these replacements. In the forecast, these replacements are selected using a Weibull with parameters alpha = 90 and beta = 2 which results in 800-1200 replacements per year consistent with current replacement rates.

Strategic Direction

Lifecycle Stages

Acquisition

Selection Criteria

- In the short/medium term maintain current selection criteria for DPT.
- In the short term identify and procure IAC compliant SF6 slimline enclosed substation units (CERM7664.06)
- In the short term investigate the viability to use Voltage Regulating Distribution Transformers (VRDT) for suitability in handling network voltage fluctuations

Procurement

- Continue to utilise current procurement function for depots.
- Continue the current period contract approach with vendors.

Supply Chain

- Continue to hold stock at all depots and larger stockpile at the warehouses
- Maintain stock holding quantities to mitigate risks against supply shortage, or increase demand due to bush fires and storms.
- *Review stock holdings* at the warehouses and suppliers based on the projected asset demand from the risk model.

Ops & Maintenance

Preventative Maintenance (Inspections):

- Continue to perform periodic inspections to identify failed or defective assets in accordance with *CEOM7005 and CEOP2474*.

Inspect. Period	Substation Asset Type	Maint/Inspect Activity
4.5 Yearly	All OH substations	Inspection as per CEOP8009
5/10/15 Yearly	UG Substations	Inspection as per CEOP2474
1 Yearly	All substation assets within bushfire prone areas	Ground/Aerial visual inspection
6 Monthly	All critical equipment	Inspection as per CEOP2034

Corrective Maintenance (Repairs):

- Continue to manage defects in accordance with CEOM7005, *CEOM7094 and CEOS5120.15.*

Breakdown Maintenance:

- Continue to carry out breakdown maintenance on Distribution Power Transformer assets in accordance with *CEOM7094 and CEOM7005*.
- Larger investments will undergo and require demonstration of a positive value calculation.

Interventions

Serviceability

- Continue to assess and rectify Overhead Distribution Power Transformer asset serviceability in accordance with *CEOM7005 and CEOS5120.15*
- Continue to assess and rectify Distribution Power Transformer assets installed in Padmount/Ground/ Chamber substation in accordance with *CEOP2474 & CEOM7804.*

Rate of Replacement

- Short/Medium – maintain current process of identifying, evaluation and replacements.

Prioritisation

- In the short term continue to prioritise replacements of DPT by severity and risk in accordance with *CEOM7005*.
- In the medium term supplement existing condition based prioritisation selection practices (CEOM7005) for DPT with additional criticality risk base selection
- Continue to assess and evaluate all interconnected assets (substation/padmount) in planning, investment and prioritisation.

Disposals

Individual Assets

- Continue to investigate opportunities to re-use and recycle assets in accordance with *CECP8074 & CEOS512.15*
- Continue to dispose of assets as per *CECP8074.01 Company Policy Asset Disposal.*

Entire Asset Variant

- Continue to dispose of assets as per *CECP8074.01 Company Policy Asset Disposal.*

Hazardous Materials

- Continue to manage hazardous materials in accordance with *CECM1000.10. (Oil & PCB's)*
- *Investigate the use of FR3 (Biodegradable oil) fluid in Distribution Power Transformers for conservation areas*

Process & Information	• Improve use of EAM as the central repository of asset information, preventative and corrective actions and test results. • Enhance asset risk-value assessments leveraging capabilities of new software platforms. • Enhance records for Distribution Power Transformer capture failure & asset profile.
People & Training	• Continue to manage training and up skilling of staff regarding inspection, condition assessment and minor repairs (CEOS5120.15)
Supply Chain	• Continue to manage spares at the depot level for F&E replacements • *Investigate opportunities* to mitigate potential supply chain risk by implementing demand forecasting and inventory allowance tools using asset risk models.