Asset Management Plan

Power Transformers

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Authorisations

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Prepared by		06/10/2022
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Responsibilities

This document is the responsibility of the Substation Asset Strategy Team, Tasmanian Networks Pty Ltd, ABN 24 167 357 299 (hereafter referred to as "TasNetworks").

The approval of this document is the responsibility of the Asset Strategy Team Leader.

Please contact the Substation Asset Strategy Team Leader with any queries or suggestions.

- Implementation All TasNetworks staff and contractors.
- Compliance All group managers.

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Reference documents

R954721 – TasNetworks Strategic Asset Management Plan

R40766 – TasNetworks Asset Management Policy

R909655 – TasNetworks Risk Management Framework

Record of revisions

Revision	Details	Date
5.0	Re-write from Transend format into TasNetworks Format and update of data	10/2017
6.0	Re-write into new TasNetworks template	10/2022

Table of contents

1 Purpose

The purpose of this document is to describe for Power Transformers and related assets:

- TasNetworks' approach to asset management, as reflected through its legislative and regulatory obligations and strategic plans;
- The key projects and programs underpinning its activities; and
- Forecast capital (**Capex**) and operational (**Opex**) expenditure, including the basis upon which these forecasts are derived.

2 Scope

This document covers Transmission Power Transformers.

3 Management strategy and objectives

This asset management plan has been developed to align with TasNetworks' Asset Management Policy, Strategic Asset Management Plan and Strategic Objectives. This management plan describes the asset management strategies and programs undertaken to manage power transformers.

The asset management objectives are to:

- manage and meet the strategic goals, measures and initiatives outlined in the TasNetworks Business Plan;
- comply with relevant legislation, licences, codes of practice, and industry standards; and
- continually adapt, benchmark, improve asset management strategies and practices, and apply contemporary asset management techniques, consistent with industry best practices.

4 Description of the asset portfolio

Power transformers are a class of voltage transformers. Voltage transformers are installed in the transmission network to convert the voltage from one level to another. Power transformers are further divided into two main categories: supply and network transformers.

Power transformers are critical parts of the overall transmission network. Power transformers are large, heavy pieces of equipment that are one of the more expensive parts of a substation. Oil is used to cool the transformer windings whilst in operation. Cooling can be improved through the use of cooling fins, cooling fans and pumped/forced oil cooling systems. The transformer can be run at a higher MVA rating when additional cooling is present. The oil used in power transformers would be detrimental to the natural environment and must be contained. The windings in power transformers are insulated with paper. This is a particular type of cellulose paper that has excellent oil absorption and electrical resistance.

Power transformers must be kept in good operating condition to ensure the reliability and stability of the network. TasNetworks runs programs and projects to maintain and replace these assets. TasNetworks strives to provide the best overall solution to our customers whilst supporting the network. There are a number of drivers behind our maintenance, inspection, testing and replacement programs. Assets are replaced when inspection and testing indicate that maintenance will no longer preserve an asset's performance. As assets age their condition invariably deteriorates.

The drivers behind replacement programs are various and relate to:

- age;
- condition;
- in-service failure;
- network performance improvement or augmentation; and
- TasNetworks' strategic objectives, such as intelligent asset management, better customer service and risk.

4.1 Network transformers

Network transformers are a critical component of the transmission network. Network transformers are installed in transmission substations across the State. Network transformers are used to transform the voltage from 220 kV to 110 kV. Network transformers have a capacity range between 150 MVA to 260 MVA. **Table 1** (below) shows the voltage ratios and 1 hour ratings of the network transformers.

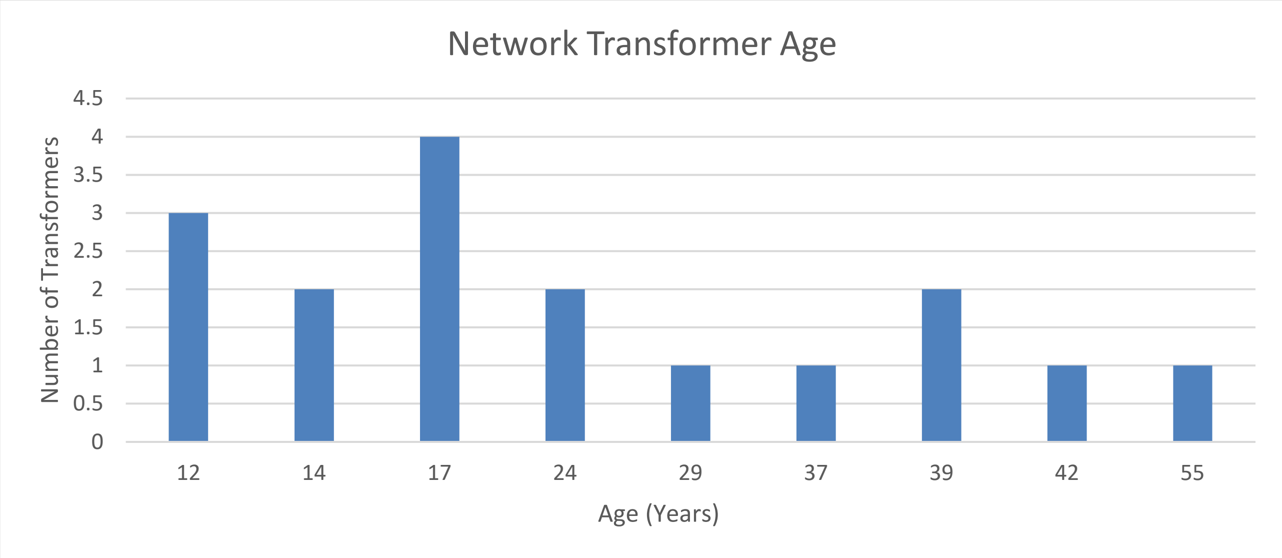
Network transformers are not connected to the distribution network. All network transformers currently installed are Autotransformers design and are oil insulated. There are currently 17 network transformers operating in the network. These vary in age from 12 to 55 years.

Table 1: Network transformer age and ratings installed in transmission substations (July 2022)

Transformer	Substation	Date Commissioned	Date of Manufacture	Age (Years)	Voltage Ratio	Continuous Ratings (MVA)
BU-T2	Burnie	21.08.2010	1.01.2010	12	220/110	150/200
CS-T4	Chapel St	1.09.2005	1.01.2005	17	220/110	150/200/260
CS-T2	Chapel St	1.03.2005	1.01.2005	17	220/110	150/200/260
CS-T3	Chapel St	1.06.2005	1.01.2005	17	220/110	150/200/260
FA-T1	Farrell	1.06.1984	1.01.1983	39	220/110	90/120/150
GT-T1	George Town	20.02.2008	1.01.2005	17	220/110	150/200/260
GT-T3	George Town	14.11.2008	1.01.2008	14	220/110	150/200
CS-T1	Chapel St	1.06.1981	1.01.1980	42	220/110	120/150/200
FA-T2	Farrell	1.06.1984	1.01.1983	39	220/110	90/120/150
HA-T2	Hadspen	1.06.1999	1.01.1998	24	220/110	150/200
HA-T1	Hadspen	1.06.1999	1.01.1998	24	220/110	150/200
GT-T2	George Town	18.07.2008	1.01.2008	14	220/110	150/200
LF-T5	Lindisfarne	20.04.2011	7.06.2010	12	220/110	150/200
LF-T4	Lindisfarne	28.04.2011	1.03.2010	12	220/110	150/200
PM-T1	Palmerston	1.06.1994	1.01.1993	29	220/110	150/200
SH-T2	Sheffield	1.01.1985	1.01.1985	37	220/110	90/150
SH-T1	Sheffield	1.01.1968	1.01.1967	55	220/110	90/150

Figure 1 (overleaf) shows the age profile of the network transformers currently in service. The economic life of a network transformer is 45 years, as detailed in the *Assessment of Proposed Regulatory Assed Lives* report prepared by Sinclair Knight Mertz (**SKM**) in August 2013. The asset life of a network transformer at TasNetworks is 60 years.

Figure 1: Network transformer age profile (July 2022)



The network transformers installed in TasNetworks' network are of varying makes and models. There are four different manufacturers of network transformers: ASEA Brown Boveri, Mitsubishi, Wilsons and Stromberg. **Figure 2** (below) shows the manufacturers of the network transformers used by TasNetworks.

Figure 2: Network transformer manufacture (July 2022)

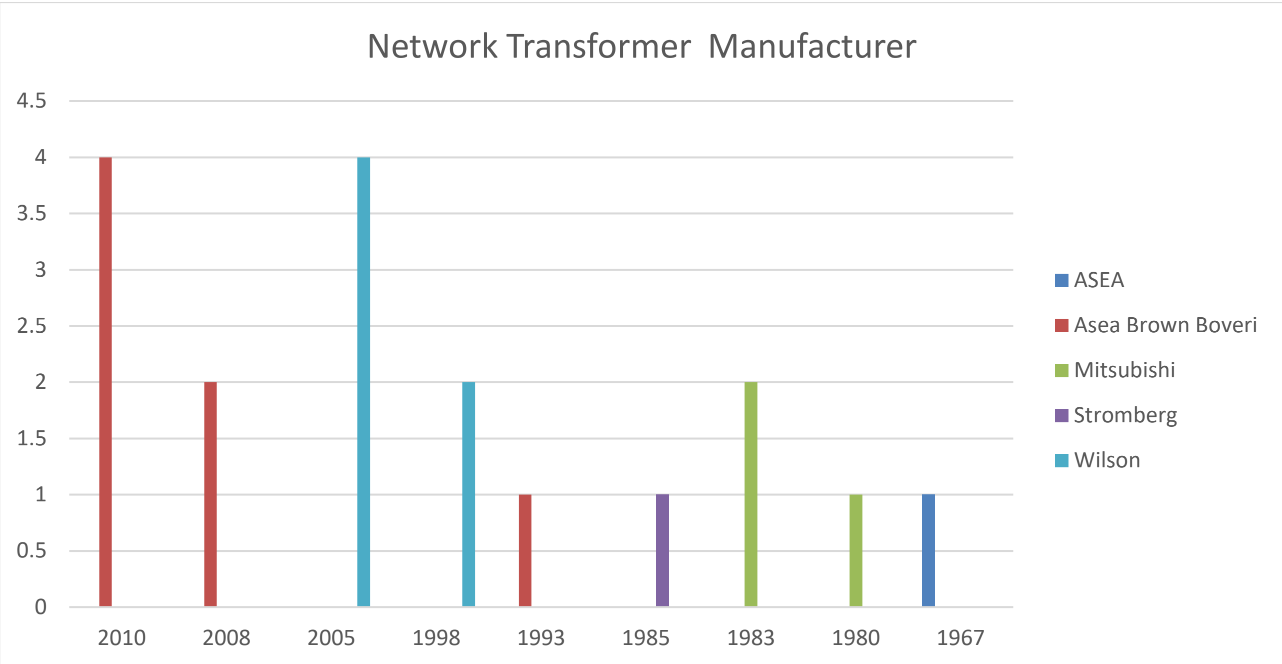


Table 2 (below) shows the configurations of each network transformer. There are four different configurations of network transformer: core form, conventional, shell form and bell tank. Bell tank configuration has a tank comprised of two sections – top and bottom. The top section is bolted to the bottom section with a gasket in-between. The join is located in the bottom third of the tank. As the gasket and flange age the tank is prone to leaking at the connection point. This is an older style of tank no longer supported by TasNetworks.

All network transformers use oil as the insulating medium. Oil is very effective in arc suppression. he presence of oil can, however, significantly increase the ferocity of fire. An explosive failure can ignite the oil and burning oil can spread the fire and delay suppression. Whilst oil continues to be the insulant used in network transformers, other insulants will be considered if they are proven to be effective.

Table 2: Network transformer construction types installed in transmission substations (July 2022)

Transformer	Substation	Construction Type	Manufacturer	Oil Volume (L)	Serial Number
BU-T2	Burnie	Conventional	Asea Brown Boveri	72000	140146
CS-T4	Chapel St	Conventional	Wilson	85500	P0401C
CS-T2	Chapel St	Conventional	Wilson	85500	P0401A
CS-T3	Chapel St	Conventional	Wilson	85500	P0401B
FA-T1	Farrell	Shell Form	Mitsubishi	32000	8437300101
GT-T1	George Town	Conventional	Wilson	85500	P0401D
GT-T3	George Town	Conventional	Asea Brown Boveri	72000	140144
CS-T1	Chapel St	Shell Form & Bell Tank	Mitsubishi	47000	8033930101
FA-T2	Farrell	Shell Form	Mitsubishi	32000	8335270101
HA-T2	Hadspen	Conventional	Wilson	72900	P9714A
HA-T1	Hadspen	Conventional	Wilson	73570	P9714/B
GT-T2	George Town	Conventional	Asea Brown Boveri	72000	140143
LF-T5	Lindisfarne	Conventional	Asea Brown Boveri	72000	140145
LF-T4	Lindisfarne	Conventional	Asea Brown Boveri	66818	509014
PM-T1	Palmerston	Conventional	Asea Brown Boveri	56000	140375
SH-T2	Sheffield	Bell Tank	Stromberg	37930	5800325
SH-T1	Sheffield	Bell Tank	ASEA	41600	5977487

4.2 Supply transformers

Supply transformers form a critical step between the transmission network and the distribution network and/or customers. Supply transformers are used to transform voltage from 220 kV or 110 kV to 44 kV, 33 kV, 22 kV, 11kV and 6.6 kV. Supply transformers have a capacity range between 4 MVA to 90 MVA. Supply transformers are of a three phase construction. Single phase supply transformers are no longer used. **Tables 3, 4, 5 and 6** show the voltage ratios and 1 hour ratings of the supply transformers used by TasNetworks. All supply transformers are oil insulated.

There are currently 102 supply transformers operating in the network. These vary in age from 0 to 72 years. **Figure 3** shows the age profile of supply transformers. The economic life of a supply transformer is 45 years, as per the *Assessment of Proposed Regulatory Assed Lives* report prepared by SKM. The asset life of a supply transformer at TasNetworks is 60 years.

The supply transformers installed in the TasNetworks network are of varying makes and models. There are 9 different manufacturers of supply transformers: AEI, Alstom, ASEA Brown Boveri, BGE/EPM, General Electric Company, Lepper, Pauwels, Savigliano and Stromberg. **Figure 4** shows the supply transformers used by TasNetworks by manufacturer.

Table 2 shows the configurations of each supply transformer. There are four different configurations of supply transformer: core form, conventional, shell form and bell tank. The Bell tank configuration has a tank comprised of two sections – top and bottom. The top section is bolted to the bottom section with a gasket in-between. The join is located in the bottom third of the tank. As the gasket and flange age the tank is prone to leaking at the connection point. This is an older style of tank no longer supported by TasNetworks.

All supply transformers use oil as the insulating medium. Oil is very effective in arc suppression. The presence of oil can significantly increase the ferocity of fire. An explosive failure can ignite the oil and burning oil can spread the fire and delay suppression. Whilst oil continues to be the insulant used in supply transformers, other insulants will be considered if they are proven to be effective.

Table 3: Supply transformer age and ratings installed in transmission substations – central region (July 2022)

Transformer	Substation	Date Commissioned	Date of Manufacture	Age (Years)	Voltage Ratio	Continuous Ratings (MVA)
AL-T1	Arthurs Lake	05.06.2013	01.08.2012	10	110/11.43 or 110/6.6	17/25
BY-T13	Boyer	01.01.1988	01.01.1988	34	110/6.6/6.6	31.5/63
BY-T14	Boyer	01.01.1988	01.01.1988	34	110/6.6/6.6	31.5/63
BY-T2	Boyer	01.01.2000	01.01.1987	35	110-88/6.6	17/24
BY-T7	Boyer	01.01.1973	01.01.1971	51	22/6.6	10/15
BY-T1	Boyer	01.04.2018	01.01.2018	4	110/22-11-6.6	17/25
DB-T1	Derwent Bridge	23.04.2008	01.01.2008	14	110/22-11	6
GO-T6	Gordon	01.01.1978	01.01.1975	47	220/22	10
MB-T4	Meadowbank	01.02.1997	01.01.1997	25	110/22-11	10
NN-T2	New Norfolk	01.03.1987	01.01.1987	35	110/22-11	18.9/31.5
NN-T1	New Norfolk	01.03.1987	01.01.1987	35	110/22-11	18.9/31.5
TU-T8	Tungatinah	07.03.2014	01.01.2010	12	110/22-11	17/25
WA-T1	Waddamana	04.08.1997	01.01.1950	72	110/22	5

Table 4: Supply transformer age and ratings installed in transmission substations – northern region (July 2022)

Transformer	Substation	Date Commissioned	Date of Manufacture	Age (Years)	Voltage Ratio	Continuous Ratings (MVA)
AV-T1	Avoca	01.01.1997	01.01.1997	25	110/22-11	17
DE-T1A	Derby	19.11.2012	01.08.2012	10	110/22-11	17/25
GT-T4	George Town	01.06.2001	01.01.2000	22	110/22	30/50
GT-T5	George Town	01.05.2003	01.01.2003	19	110/22	30/50
HA-T3	Hadspen	17.02.2006	01.01.2005	17	110/22	30/50
HA-T4	Hadspen	13.12.2007	01.01.2005	17	110/22	30/50
MY-T1	Mowbray	22.05.2009	01.01.2008	14	110/22	30/50
MY-T2	Mowbray	26.05.2006	01.01.2004	18	110/22	30/50
NW-T1	Norwood	01.06.1995	01.01.1995	27	110/33-22-11	30/50
NW-T2	Norwood	01.06.1979	01.01.1979	43	110/22-11	30/37.5/50
PM-T4	Palmerston	11.09.2006	01.01.2006	16	110/22-11	17/25
PM-T3	Palmerston	01.06.2003	01.01.1998	24	110/22-11	17/25
SD-T2	Scottsdale	01.01.1985	01.01.1983	39	110-88/22	19/31.5
SD-T1	Scottsdale	01.01.1985	01.01.1983	39	110-88/22	19/31.5
SL-T1	St Leonard	10.07.2012	01.01.2012	10	110/22	36/60
SL-T2	St Leonard	10.07.2012	01.01.2012	10	110/22	36/60
SM-T1	St Marys	01.01.1985	01.01.1966	56	110-88/22-11	10
SM-T2	St Marys	01.01.1985	01.01.1966	56	110-88/22-11	10
TR-T1	Trevallyn	01.01.1999	01.01.1998	24	110/22	30/50
TR-T2	Trevallyn	01.01.1999	01.01.1998	24	110/22	30/50
TR-T3	Trevallyn	01.01.2000	01.01.1999	23	110/22	30/50

Table 5: Supply transformer age and ratings installed in transmission substations – northern west region (July 2022)

Transformer	Substation	Date Commissioned	Date of Manufacture	Age (Years)	Voltage Ratio	Continuous Ratings (MVA)
BU-T6	Burnie	01.06.1971	01.01.1970	52	110/22-11	30/60
BU-T7	Burnie	01.06.1971	01.01.1970	52	110/22-11	30/60
DP-T3	Devonport	21.06.2019	01.01.1999	23	110/22	30/40/50
DP-T1	Devonport	01.06.1996	01.01.1996	26	110/22	20/30
DP-T2	Devonport	01.06.1996	01.01.1996	26	110/22	20/30
EB-T2	Emu Bay	01.01.1973	01.01.1973	49	110/22-11	20/40
EB-T3	Emu Bay	01.01.1973	01.01.1973	49	110/22-11	20/40
NT-T1	Newton	26.03.2013	01.01.1970	52	110/22-11	15/22.5
NT-T2	Newton	01.03.2013	01.01.1970	52	110/22-11	15
PL-T1	Port Latta	01.06.1967	01.01.1967	55	110/22	15/22.5
PL-T2	Port Latta	01.06.1967	01.01.1967	55	110/22	15/22.5
QU-T1	Que	24.09.2008	01.01.1979	43	110/22-11	30/37.5/50
QT-T3	Queenstown	08.04.2009	29.06.2008	14	110/22-11	17/25
QT-T1	Queenstown	30.04.2014	20.02.2014	8	110/22-11	17/25
QT-T4	Queenstown	14.05.2009	29.06.2008	14	110/22-11	17/25
QT-T2	Queenstown	01.05.2003	01.01.2003	19	110/22-11	17/25
RA-T2	Railton	01.01.1982	01.01.1982	40	110/22-11	30/50
RA-T1	Railton	01.01.1982	01.01.1982	40	110/22-11	30/50
RB-T3	Rosebery	25.07.2019	01.01.1983	39	110/44-22	20/30
RB-T4	Rosebery	01.01.1983	01.01.1982	40	44/22	6/10
RB-T1	Rosebery	08.11.1968	08.11.1968	54	110/44-22	20/30/36
RB-T2	Rosebery	22.10.1968	22.10.1968	54	110/44-22	20/30/36
RB-T5	Rosebery	21.01.2022	01.01.2022	0	44/22	6
SR-T3	Savage River	01.01.1967	01.01.1967	55	110/22	15/22.5
SR-T2	Savage River	01.01.1967	01.01.1967	55	110/22	15/22.5
SH-T5	Sheffield		01.01.2018	4	110/22-11-6.6	17/25
ST-T1	Smithton	01.08.2003	01.01.2003	19	110/22	21/35
ST-T2	Smithton	01.08.2003	01.01.2003	19	110/22	21/35
UL-T2	Ulverstone	01.01.1983	01.01.1983	39	110/22-11	30/45
UL-T1	Ulverstone	01.01.1978	01.01.1975	47	110/22-11	30/45
WV-T3	Wesley Vale	01.06.1970	01.01.1970	52	110/22-11	15/25
WV-T4	Wesley Vale	01.06.1971	01.01.1970	52	110/22-11	15/25

Table 6: Supply transformer age and ratings installed in transmission substations – south region (July 2022)

Transformer	Substation	Date Commissioned	Date of Manufacture	Age (Years)	Voltage Ratio	Continuous Ratings (MVA)
BW-T2	Bridgewater	01.06.1980	01.01.1980	42	110/22-11	21/35
BW-T1	Bridgewater	01.06.1980	01.01.1980	42	110/22-11	21/35
CS-T6	Chapel Street	01.06.1984	01.01.1983	39	110/11/11	36/60
CS-T5	Chapel Street	01.06.1984	01.01.1983	39	110/11/11	36/60
CR-T2	Creek Road	01.05.2002	01.01.2001	21	110/33	30/48/60
CR-T4	Creek Road	01.04.2002	01.01.2001	21	110/33	30/48/60
CR-T3	Creek Road	01.12.2001	01.01.2001	21	110/33-22	30/48/60
EL-T2	Electrona	10.12.2008	27.06.1997	25	110/22-11	17/25
EL-T1	Electrona	22.08.2008	29.06.2008	14	110/22-11	17/25
HR-T1	Huon River	05.06.2007	07.02.2007	15	110/22-11	17/25
KE-T1	Kermandie	01.06.1962	01.01.1961	61	110/22-11	10
KE-T2	Kermandie	01.01.1962	01.01.1961	61	110/22-11	10
KI-T1	Kingston	01.06.1980	01.01.1979	43	110/22-11	21/35
KI-T4	Kingston	11.04.2012	01.06.2011	11	110/33	42/60
KI-T2	Kingston	01.01.1980	01.01.1979	43	110/22-11	21/35
KI-T3	Kingston	11.04.2012	01.06.2011	11	110/33	42/60
KR-T1	Knights Road	01.01.1987	01.01.1987	35	110/22-11	12/20
KR-T2	Knights Road	01.01.1987	01.01.1987	35	110/22-11	12/20
LF-T2	Lindisfarne	17.12.2019	01.11.2019	3	110/33	30/60
LF-T3	Lindisfarne	23.04.2020	18.03.2020	2	110/33	30/60
MT-T1	Mornington	10.05.2011	01.01.2010	12	110/33	42/60
MT-T2	Mornington	18.05.2011	01.01.2010	12	110/33	42/60
NH-T1	North Hobart	01.01.1977	01.01.1976	46	110/11/11	30/45/45
NH-T2	North Hobart	01.01.1977	01.01.1976	46	110/11/11	30/45/45
RI-T5	Risdon	03.11.2006	01.01.1995	27	110/33-22-11	30/50
RI-T1	Risdon	01.04.2001	01.01.2001	21	110/11/11	65/90
RI-T6	Risdon	26.05.2006	01.01.2005	17	110/33	30/50
RI-T2	Risdon	01.04.2001	01.01.2001	21	110/11/11	65/90
RI-T3	Risdon	01.12.2001	01.01.2001	21	110/11/11	65/90
RI-T4	Risdon	16.01.2007	01.01.2000	22	110/33-22-11	30/50
RK-T2	Rokeby	01.01.1982	01.01.1981	41	110/22-11	21/35
RK-T1	Rokeby	01.01.1982	01.01.1981	41	110/22-11	21/35
SO-T1	Sorell	06.04.2011	01.01.2010	12	110/22	36/60
SO-T2	Sorell	07.03.2011	01.01.2010	12	110/22	36/60
TB-T1	Triabunna	07.09.2006	01.01.2006	16	110/22	17/25
TB-T2	Triabunna	18.10.2006	01.01.2006	16	110/22	17/25

Figure 3: Supply transformer age profile (July 2022)

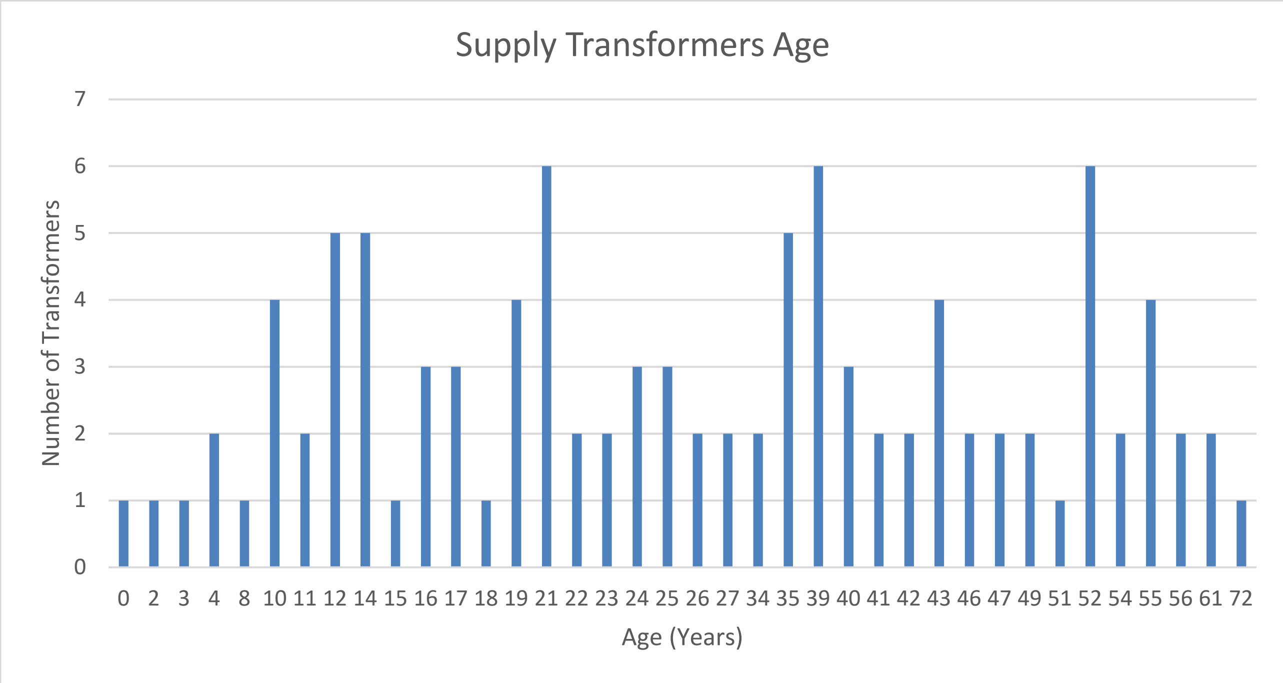


Figure 4: Supply transformer age profile and manufacturer (July 2022)

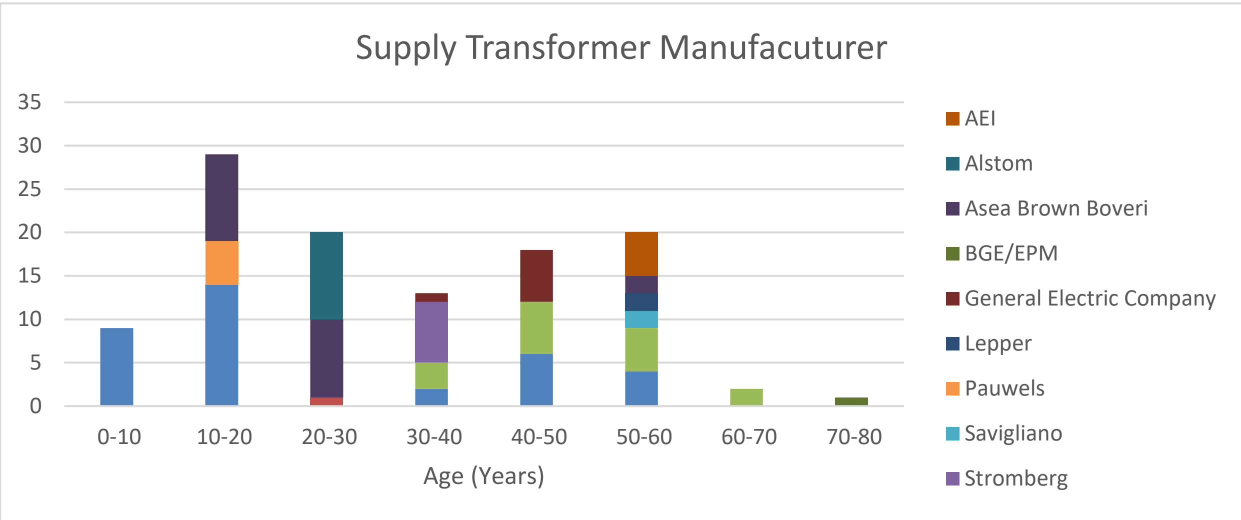
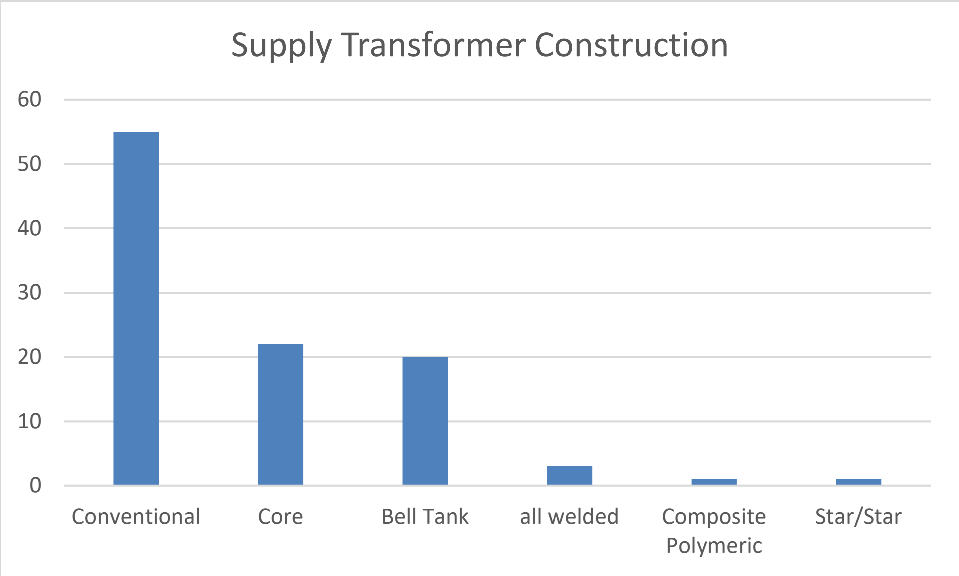


Figure 5: supply transformer construction type (July 2022)



5 Associated risk

5.1 Risk management framework

TasNetworks has developed a Risk Management Framework for the purposes of assessing and managing its business risks, and for ensuring a consistent and structured approach for the management of risk is applied. An assessment of the risks associated with the power transformer has been undertaken in accordance with the Risk Management Framework.

TasNetworks has introduced a Health Based Risk Management (**HBRM**) framework for the quantification of asset risks.

The asset management drivers are:

- safety of our people and customers;
- reliability of supply to our customers;
- security of supply to our customers; and
- value of supply to our customers.

Due to the level of risk identified in some of the assessment criteria a requirement to actively manage these risks has been identified.

5.2 Performance data

TasNetworks monitors equipment performance by recording a defect notification against the equipment record in the SAP Enterprise Asset Management system. These records are interrogated by asset engineering personnel who action or note the defect as is appropriate. Some defects require immediate attention whilst others will be monitored for trends or deterioration. TasNetworks is currently working to improve the data collected to enable better interrogation and analysis. This analysis will be used to feed HBRM tools and drive better customer outcomes.

TasNetworks also carries out condition monitoring programs. The goal of these programs is to proactively gather data regarding the condition of the assets. Power transformers are regularly inspected to determine if there are any hot spots or if the transformer as a whole is running hot. Transformer oil is also sampled to analyse if any incipient faults are evolving within the transformer. See *Power Transformers Appendices - Appendix A Insulating Oil* for analysis and condition classification.

Power transformers installed in TasNetworks' transmission substations are prone to specific failure modes. Failure modes most commonly relate to:

- windings;
- tap changers;
- bushings; and
- tanks.

5.3 Asset risks

There are two main drivers for risk outcomes related to power transformers: failure to operate and catastrophic failure. Failure to operate results in an asset not being able perform its intended function. A failure to operate will impact the network's ability to deliver power to customers. Catastrophic failure occurs when the power transformer explodes or catches fire. A catastrophic failure may result in one or all of the following:

- loss of power supply;
- injury to persons;
- impact the environment;
- equipment damage; and
- unplanned replacement.

Loss of power supply and the duration of the outage will impact the safety of our people and customers, reliability of supply to our customers, security of supply to our customers and value of supply to our customers.

TasNetworks develops its transformer program taking into consideration asset condition, legal and regulatory obligations, performance and reliability requirements, business strategies and synergies with other work programs. The aim is to, as far as is reasonably practicable, extend the life of assets and then replace them before failure occurs.

Condition monitoring of power transformers allows for risk assessments of an asset's ability to operate reliably and efficiently. These risk assessments determine whether TasNetworks' will maintain, refurbish or replace power transformers and the optimal timing of these actions. Due to the critical nature of these assets, transformers identified as requiring maintenance, refurbishment or replacement are proactively planned to mitigate the risk of in-service failure.

5.3.1 Loss of power supply

Power transformers support the supply of power to households and major industrials. Supply transformers supply 242,000 private dwellings and approximately 542,000 residents. Network transformers directly supply major industrial (**MI**) users of electricity. Network transformers deliver load to supply transformers and acts as interconnectors between 220 kV and 110 kV. Network transformers also facilitate the injection of renewable energies such as wind farms into the network. Disruption in supply directly impacts these customers.

The arrangement at transmission substations is to have an N-1 arrangement. This means there is a secondary option to supply the power. However, this can take time to switch to the new arrangement. Depending on the arrangement the switching time can vary. If a transformer were to catastrophically fail in an explosion, the time to switch would be significantly extended. This time extension is due to having to put out any fire and make safe before switching can occur.

Where there is an N-1 arrangement the failure of a transformer could take hours to switch between supply arrangements. The switching time can vary depending on the arrangement. Transformers can take 6 to 8 days to replace with an available spare unit. There could be a reduced capacity for load, in some of the substations, with only one transformer. If there is a catastrophic failure this time could be extended to two weeks in order to clean up the site and make ready for the replacement transformer.

The following controls are in place to mitigate the likelihood of these risks:

- N-1 arrangements;
- spares;
- fire walls;
- oil containment;
- switching; and
- protection and control schemes.

5.3.2 Injury to persons

Persons in the vicinity of a catastrophic failure may be impacted in a number of ways. If a person is close to a power transformer when it explodes the person could be covered in burning oil. Projectiles from the explosion could impact persons on the scene. People are not often in close range of the power transformers and so it is unlikely that oil or projectiles would impact a person. Smoke inhalation is also of concern. Smoke can spread into the local area. Burning oil could impact the repertory systems of at risk members of the public. First responders such as fire fighters may also be impacted by smoke or secondary explosions. First responders in this instance are the fire brigade, who are trained in the containment and approach to oil fires.

The following controls are in place to mitigate the likelihood of these risks:

- access to authorised persons only;
- electric fencing;
- personal protective equipment;
- cameras; and
- swipe card access and monitoring.

5.3.3 Impact to the environment

TasNetworks' fleet of power transformers are oil filled. This oil is detrimental to the natural environment. Oil leaks and spills could seep into the soil, impact waterways, disturb flora and fauna in the area. Where a catastrophic failure occurs the oil will both spill from the transformer and catch fire. Burning oil will produce significant amounts of smoke. The smoke is harmful to breathe. Smoke will travel high into the air and travel quickly beyond substation boundaries. Smoke can impact both employees, first responders and the local communities. The reaction to breathing the smoke could be severe if a person has respiratory related health concerns.

There following controls are in place to mitigate the likelihood of these risks:

- oil bunds are in place;
- protection and control alarms;
- a protocol for contacting first responders; and
- environmental team to advise on clean up.

5.3.4 Unplanned replacement

There is a significant difference between the planned and unplanned replacement of assets. The planned replacement of assets allows for the equipment to be purchased in advance, planned switching to occur and interruptions to customers to be minimised. In the event of an unplanned failure none of these happen. Instead the process for replacement begins at the time of failure. As discussed in 5.3.1, unplanned switching could take much longer than planned switching, increasing the time customers are without or have reduced supply.

The lead time for assets such as power transformers is over twelve months. Installation of the asset once procured is done at the earliest possible time. During the time it takes to procure and install the transformer, the network is left without an N-1 capacity in that location. This means that the supply for entire areas are dependent on one transformer. Should this transformer fail the communities and businesses supplied from this substation will be without power until the replacement transformer is installed. Further, the stability of the network may become increasingly marginal during this time.

There are protocols and switching available to mitigate any loss of capacity and stability. Depending on the location of equipment failure, the network may be constrained. This might impact the ability for the network to support export to the mainland of Australia.

The following controls are in place to mitigate the likelihood of these risks:

- spares holdings; and
- switching.

5.3.5 Equipment damage

When assets fail catastrophically they can explode, sending projectiles through the air. These could be pieces of bushings, main tank, oil, nuts, bolts or parts of external piping. The trajectory of these projectiles could be in any direction. They may damage equipment in the same bay or neighbouring bays by puncturing holes or breaking insulators. Oil can also be spread by the explosion. Transformer oil will usually be on fire when it is involved in an explosion. Burning oil can be spread across the ground, spreading the fire to other assets.

The following controls are in place to mitigate the likelihood of these risks:

- blast (fire)walls;
- oil bunds; and
- protocol for contacting first responders.

Blast walls are erected between power transformers for the explicit purpose of protecting the second transformer should an explosion occur. Oil bunds are constructed around the transformer for the purpose of collecting spilt oil and containing it. Oil bunds will not contain all of any oil that becomes airborne as part of an explosion. Fire response involves the local fire department responding with suitable fire suppressants.

Table 7: Summary of asset risks

Risk Identification		**Risk Analysis (Inherent)**				
Asset	**Risk Description**	**Category**	**Likelihood**	**Consequence**	**Risk Rank**	**Treatment Plan Yes / No**
Power Transformer	Equipment failure	Safety and People	Possible	Major	High	Yes
		Financial	Unlikely	Major	Medium	
		Customer	Unlikely	Moderate	Medium	
		Regulatory Compliance	Unlikely	Minor	Low	
		Network Performance	Unlikely	Major	Medium	
		Reputation	Unlikely	Minor	Low	
		Environment & Community	Rare	Minor	Low	

6 Whole of life management plan

6.1 Preventive and corrective maintenance (Opex)

TasNetworks undertakes inspections programs and routine maintenance. Routine maintenance refers to any maintenance task that is done on a planned and ongoing basis to identify and prevent problems before they result in reduced asset performance or equipment failure. These programs are undertaken to monitor condition. Condition data is used to identify where risk of equipment failure is increasing or where performance is reducing.

Risks are managed and mitigated by taking timely action to rectify defects or implement controls. Routine maintenance addresses the identified risks of equipment failure or reduced performance. In addition to routine maintenance, minor repairs may be undertaken. Minor repairs are repairs that are one off repairs undertaken on an as needed basis, rather than a planned or ongoing basis. Minor repairs also address the risk of in service failure or reduced performance.

A schedule of inspections programs and routine maintenance can be found in *Power Transformers Appendices - Appendix B*.

TasNetworks captures the results and insights from condition and maintenance activities in a document known as a condition assessment report (**CAR**). CARs are reviewed and updated every 24 months in alignment with the results of transformer insulating oil analysis. This is to ensure trends are identified and reported in a timely manner to ensure action can be taken to maximise the value of assets.

CARs also review asset failure history. This history is used to inform the likelihood of consequences. The Total Qualified Risk (**TQR**) tool has been developed by the business to quantify risk. This tool converts the risk and consequence into a risk value.

Below are descriptions of the programs currently undertaken in relation to power transformers. These programs cover off the Opex component of power transformer management and maintenance. A detailed maintenance schedule can be found in *Power Transformers Appendices – Appendix B – Routine maintenance*.

6.1.1 Condition monitoring

Condition monitoring and assessment criteria broadly fall into the following categories:

- routine dissolved gas analysis (**DGA**) sampling;
- electrical testing (bushings);
- tap-changer maintenance; and
- auxiliary equipment testing.

6.1.1.1 DGA sampling

Routine sampling of the complete transformer fleet is conducted on a two-yearly cycle, with the exception that transformers that have been in service for more than 35 years will have increased oil sampling (i.e. annually) to more closely monitor their condition.

Since 2018, a new sampling regime for new transformers and transformers which have undergone major refurbishment has been put in place. This has included installing a portable DGA unit at any new or major refurbished transformer for the first six months after its energisation. This is an innovative measure to provide real-time identification of any gassing issues which may occur during this initial life cycle phase. This aligns with strategic thinking based on the “bath tub” failure cycle for assets. A bathtub curve is a hazard function showing an increased failure rate in the early life and an increasing failure rate in late life with the flat part of the bathtub curve being called useful life. The bathtub curve highlights that failures may occur early in an asset’s life cycle and if not then many years of satisfactory service is expected prior to end of life replacement/retirement.

6.1.1.2 Electrical testing

Transformer electrical testing is performed in the factory acceptance test and site commissioning, which acts as fingerprint tests for later comparison should more electrical tests be required.

Electrical tests are again required when DGA test results indicate the abnormally high generation or concentration of certain gases in the insulating oil and after severe faults seen by the transformer.

Transformer bushings are subjected to electrical testing as a means of condition monitoring. Transformer bushings of an oil impregnated paper design, installed on transformers have provided reliable service with no instances of failure. Due to the reliability of oil impregnated paper bushings, electrical tests are not required for the first 18 years of service. This approach aligns with industry practice.

6.1.1.3 Tap-changer maintenance

Tap-changer maintenance is carried out every six years on most transformers, with a small number requiring maintenance on a three yearly cycle. Maintenance is based on either the number of operations of the switch mechanism or on a time-based frequency. Maintenance timings can be brought forward based on degradation of tap changer oil results.

6.1.1.4 Auxiliary equipment testing

Routine test on auxiliaries such as Buchholz, OTI/WTI, and pressure relief device are carried out every six years in conjunction with other routine tests.

6.2 Non-routine maintenance

Minor and major asset defects that are specifically identified during asset inspections and routine maintenance or through other ad-hoc site visits are prioritised and rectified as per the recommendations set out in TasNetworks' CAR and general asset defects management process.

The methodology used to develop and manage non-routine maintenance is adjusted to meet the option analysis completed specific for the defect. This is to meet the performance criteria set out in TasNetworks' risk framework, with the objective to return to service and prevent asset failure.

6.3 Future of maintenance

As technology continues to improve, TasNetworks recognises that the methods of proactively approaching life-cycle asset management may need to be modernised. TasNetworks keeps abreast of new and upcoming technologies through TasNetworks' participation in various benchmarking and best practice activities. TasNetworks is an active member of CIGRE and ITOMS and participates in industry conferences both locally and internationally.

TasNetworks is a relatively small transmission network when compared to mainland Australian and international companies. Larger entities are able to trial new technology with a lower overall risk, as the risk of one asset failure is a much smaller proportion of their network. In comparison a single asset failure on a small network has a potentially large impact on overall performance. For this reason, TasNetworks takes a conservative approach to new technology. When technology has been proven in the field and the risks are known, it is then adopted. This protects our customers and the communities from higher prices and unreliable service. Initiatives that are likely to be pursued in the future are represented in **Table 8**.

Table 8: Technology and innovation initiatives

Initiative	Rationale	Driver
Online condition monitoring	• The introduction of new measurement techniques and technologies. • Increased utilisation of intelligent condition monitoring systems.	• Improved assessment of asset condition. • Improved life-cycle management.

6.3.1 Summary of Opex expenditure

Table 9: Summary of Opex programs and expenditure

Project/Program	Func. Area	Expenditure ($)										
		Financial year	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29
Preventative Maintenance of Supply Transformers	PMNT	Expenditure ($)	88,245	89,213	88,959	89,040	89,000	88,959	88,959	88,959	88,959	88,959
Preventative Maintenance of Supply Transformers	PMST	Expenditure ($)	537,279	544,499	547,071	542,743	542,500	547,071	547,071	547,071	547,071	547,071

6.4 Reliability and quality maintained (Capex)

Capital expenditure (**Capex**) is work that significantly increases the life of an asset or is for the replacement of an asset.

Power transformers are critical to the safety, reliability, security and value to our customers. The criticality of these assets increases the risk associated with in-service failures and reduced performance. Where routine maintenance is no longer able to ensure the performance or safety of assets, those assets are prioritised for replacement prior to an in-service failure occurring.

The drivers for asset replacement are usually either deterioration in their condition or other specific issues that present risks that cannot be addressed through other means. These risks are defined in Section 5. Asset failures can also result in a need for asset replacement.

6.4.1 Transformer replacement program (RENTF)

The transformer replacement program (**RENTF**) relates to the replacement of power transformers. Power transformers are replaced based on their condition, performance or as the result of in-service failure. The approach to asset replacement is value based. The risk of asset failure (likelihood and consequence) is balanced against the value of other programs proposed by the business. In this way the business can deliver the best return on expenditure for its customers.

Every potential replacement is prioritised based on an assessment against the following criteria:

- risk to public safety i.e. level of exposure e.g. enclosure type, location;
- criticality of the installation and consequences if a failure occurred;
- condition;
- likelihood of failure;
- compliance; and
- ability to maintain the asset.

This approach has identified the following power transformer replacements to be undertaken in the R24 period:

- Rosebery T1;
- Rosebery T2;
- Savage River T2;
- Savage River T3;
- Sheffield T1;
- St Marys T1;
- St Marys T2; and
- Waddamana T1.

TasNetworks approaches asset replacement by considering all viable options available. For power transformers there are a number of basic options considered. Other options are also considered if and where practicable to do so. The basic options cover substations where there are two power transformers requiring replacement. Because of the different arrangements at different substations not all options will be applicable to all situations. The basic options considered are outlined below.

6.4.1.1 Option 0 – Do nothing

Option 0 effectively involves taking no action beyond routine maintenance and inspection routines. This means that although these preventative maintenance programs are no longer enough to sustain performance, the transformer(s) in question would remain in service until failure occurred. This option demonstrates the current risk and potential consequences. This is the baseline option that all other options are compared against. The benefit of other options can be demonstrated through the difference between the base option 0 and the option being discussed. In this way the leas risk option can be identified.

6.4.1.2 Option 1 – Replace one transformers to standard

This option describes the situation where only one transformer requires replacement. This option looks at replacing that transformer with a new transformer. The new transformer will meet the current TasNetworks standards. When compared to other work in the business this option may be preferred, as the capital is best spent on the highest value projects and/or programs.

6.4.1.3 Option 2 – Replace two transformer to standard

This option describes the situation where two transformers require replacement. This option looks at replacing the existing transformers with a new transformers. The new transformers will meet the current TasNetworks standards. When compared to other work in the business this option may be preferred as the capital is best spent on the highest value projects and/or programs.

6.4.1.4 Option 3 – Delay replacement of transformers to standard

This option is identical to option 1 or 2, except that the investment is to occur 5 years later. Effectively this option tests the timing of replacements between two future reset periods. This compares the value of replacing the transformers now versus into the future. When compared to other work in the business this option may be preferred as the capital is best spent on the highest value projects and/or programs.

6.4.1.5 Option 4 – Refurbish transformer(s)

This option includes the refurbishment of 1 or 2 transformers. The aim of this approach is to extend the life of the transformers at a lower cost than replacement. When compared to other work in the business this option may be preferred as the capital is best spent on the highest value projects and/or programs. If a units has already been refurbished, however, there is considered to be little value in refurbishing the unit a second time.

6.4.1.6 Option 5 – Refurbish one of two transformers

This option is where there are two transformers requiring replacement. The aim of this option is to explore the benefits of refurbishing the transformer in the worst condition. This approach can significantly lower the risk of asset failure at a reduced cost. When compared to other work in the business this option may be preferred as the capital is best spent on the highest value projects and/or programs.

6.4.1.7 Option 6 – Refurbish one and replace one transformer

This option describes the situation where two transformers require replacement. The aim of this option is to explore the benefits of refurbishing one transformer and replacing the transformer that is in the worst condition. This approach can significantly lower the risk of asset failure, for a reduced cost. When compared to other work in the business this option may be preferred as the capital is best spent on the highest value projects and/or programs.

6.4.1.8 Option 7 – Replace one transformer and run the other to failure

This option describes the situation where two transformers require replacement. The aim of this option is to explore the benefits of replacing the transformer that is in the worst condition whilst running the other transformer to failure. This approach can significantly lower the risk of asset failure, at a reduced cost. When compared to other work in the business this option may be preferred as the capital is best spent on the highest value projects and/or programs.

6.4.1.9 Option 8 – Replace both transformers with one transformer

This option describes the situation where two transformer require replacement. The aim of this option is to explore the benefits of replacing both transformers with one transformer large enough to perform the duties of the two transformers that have been in service. This approach could be beneficial where a larger standard transformer is suitable. This option removes the N-1 arrangement in some cases and needs to be investigated by network performance to ensure the option is viable. When compared to other work in the business this option may be preferred as the capital is best spent on the highest value projects and/or programs.

6.4.1.10 Option 9 – Replace transformer(s) with like for like

This option looks at replacing transformers with like for like, regardless of the standard. This is considered where the transformers being replaced are significantly different in MVA from the standard transformers prescribed by TasNetworks. This option tests the validity of maintaining the current standard of transformers. The transformer pool has been standardised to minimise expenditure by minimising spares holding requirements. The fewer variations of transformer in the fleet the fewer spares are required to support the fleet. This in turn reduces the expenditure on holding spares. When compared to other work in the business this option may be preferred as the capital is best spent on the highest value projects and/or programs.

6.4.1.11 Option 10 – Replace transformers and modernise

This option looks at the whole site and addresses any other configuration, layout issues and/or functional risks that may be present. Many of the sites are approaching 70 years of age. Since their construction TasNetworks' standards and practices will have changed, as will Australian standards and best practices. Currently the network is preparing for significant future change with the changing electricity generation environment in Australia. This option considers these changes and future proposals to ensure the safety, reliability, security and value are maximised for customers, today and into the future. When compared to other work in the business this option may be preferred, as the capital is best spent on the highest value projects and/or programs.

6.4.2 Details of future Capex projects

The business uses the Copperleaf software program to compare projects and programs across the business to drive the best value for our customers. Copperleaf does this by comparing investments and risks to give a balanced business expenditure over the coming reset period. The output of Copperleaf in relation to power transformers is summarised in **Table 10** (below)**. Table 10** outlines the power transformer projects proposed for the R24 revenue reset period.

Table 10: Project details

Project/Program description	Functional area	Link to Copperleaf
Rosebery T1 and T2	RENTF	PRJ000861
Savage River T2 and T3	RENTF	PRJ000633
Sheffield T1	RENTF	PRJ000637
St Marys T1 and T2	RENTF	PRJ000634
Waddamana T1	RENTF	PRJ000635

6.5 Spares management

TasNetworks' approach to spares management is outlined in the *System Spares Policy R517373*. At a minimum there shall be one available spare for any power transformer in the network. Where spares are used they must be booked to the project that installed them. Booking a spare to the project is the same as booking any item to a project from the warehouse.

The spare power transformer catalogue cost must be booked to the project and a replacement spare ordered. The catalogue cost is the value associated with the spare in the SAP inventory catalogue. If a value doesn't exist the replacement cost shall be used as the catalogue value. A replacement spare must be ordered immediately to replace the spare used.

6.6 End of life management

The SKM assessment of proposed regulatory asset lives is the point of reference for asset life and references 45 to 60 years for power transformers. The life of power transformers as defined by the AER is 45 years. TasNetworks strives to maximise asset life where it is in the best interests of the customer to do so. TasNetworks has had power transformers in its fleet that are still in service at 72 years of age, although by that time they had been relocated to an area of much lower MVA than their name plate rating.

Once an asset has reached the end of its useful life it is removed from service and decommissioned. The capital replacement project is responsible for the removal and disposal of the decommissioned assets. Where assets are useful as spares or can be effectively refurbished they are identified before the project is estimated. Associated refurbishment costs are associated with the capital replacement project.

Where an asset is to be disposed of it is done so under the replacement project. The project is responsible for the timely, safe and environmentally sound disposal of assets. Wherever possible the recycling of assets or component parts is encouraged.

All asset management and information systems must be updated. Data relating to decommissioned assets must be updated to reflect the removal of those assets. Similarly data relating to any and all installed assets must also be updated. SAP is currently the computer managed maintenance system used at TasNetworks and is the source of truth for asset information. It is imperative that this is kept current and accurate and it is the responsibility of the project to ensure all data is updated as part of the project closeout.

7 Related standards and documentation

The following documents have been used to either in the development of this management plan, or provide supporting information to it:

TasNetworks documents

Power Transformer Asset Management Plan Appendices - R2320590

Standards

Power Transformers - AS/NZS 60076

On-Load Tap Changers - Part1 and 2 - AS 60214

Insulation Oil for Transformers and Switchgear - AS 1767

Insulated bushings - AS/NZS60137

Network Transformers Standard - R527893

Supply Transformers Standard - R527890

System Spares Policy - R517373

Regulation compliance

National Energy Regulator

Australian Energy Regulator

Local government regulations