AusNet Electricity Services Pty Ltd

Transmission Revenue Reset 2017 – 2022

Appendix 4A: Network Capital Expenditure Overview – 2017 to 2022

Submitted: 30th October 2015

Revision History

Version	Date	Sections	Changes made:	Amended by:
0.1	12/09/2015	All	Document created	Tim Gowland
1	29/10/2015	All	Corrections	Priyantha Seneviratne

Review Record

The following stakeholders have reviewed this document:

Stakeholder Name:	Title:
John Dyer	Networks Strategy Manager

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1 Introduction

As part of its revenue proposal, AusNet Services must submit a forecast of capital expenditure for the relevant regulatory period, in accordance with National Electricity Rules (NER) clause 6A.6.7(a). This report describes the forecast, shown in Table 1, explains how the forecast was developed, describes the drivers of expenditure, and outlines the benefits of the proposed capital program. AusNet Services' capex forecast only relates to the replacement of shared transmission network assets and transmission connection assets, and excludes any expenditure to augment the transmission system.

All forecasts set out in this document are in direct terms (exclude overheads and escalations) and in real 2015 dollars.

Capital Program	17/18	18/19	19/20	20/21	21/22	Total Cost
Existing Committed Projects	42,434	5,560	-	-	-	47,994
Major Projects	31,952	43,831	57,591	53,385	37,894	224,653
Stations	17,053	19,009	19,097	18,567	18,567	92,293
Lines	9,274	12,705	9,186	9,186	9,003	49,353
Secondary & Protection Program	20,805	17,688	15,005	14,280	15,117	82,895
Communications Program	10,026	12,023	14,076	12,265	8,814	57,204
Total Network (Excluding Overheads and escalation)	**131,544**	**110,816**	**114,955**	**107,683**	**89,395**	**554,393**

Table 1 – Capital expenditure 2017 – 2022 ($000s, 2015 direct costs)

The capital work planned for the forthcoming regulatory period is driven by:-

- The requirement to meet our obligations to provide a safe, reliable supply of electricity by replacing assets which have reached the end of their serviceable lives.
- The age and condition of assets and the profile of asset replacement which is required.
- Key planning assumptions, including the value of customer reliability.
- Emerging market trends that include reduced consumption and the risk of reduction in utilisation for some parts of the network.

We have also sought and obtained stakeholder feedback and this has been incorporated into the proposed capital expenditure program.

Safety, both for the general public and for its employees, remains the highest priority for AusNet Services. The projects funded by the proposed capex all have, to a larger or smaller degree a safety aspect, as when equipment fails the safety risk increases. Failure of high voltage plant poses the risk of shocks, electrocution, explosion and fire for people in the vicinity. For secondary equipment and communications failure the risks are that the equipment will not be properly controlled and monitored or that protection systems may fail to detect and isolate a fault. This may result in damage to or failure of plant and outages that will affect the ability of the transmission system to supply its customers.

After safety, the primary driver is replacement of assets so that AusNet Services is able to meet its obligations to provide a reliable supply. AusNet Services must also comply with its Transmission Licence conditions and national and state electricity industry legislation, rules, standards and regulations. Our asset management practices deliver a balance between total life cycle cost and quality, safety, reliability and security of the electricity supply. Our replacement timing is based on economic evaluation so that the timing of the investment is as efficient as possible.

The age and condition of the Transmission system assets reflects the historical pattern of development of the Victorian network. Given that a significant proportion of the network is at or approaching the end of its economic life, asset replacement due to condition continues to drive capital expenditure requirements. However, expenditure will not perfectly mirror the original investment profile in terms of timing and cost. This is because effective asset management, based on condition rather than age, enables efficient deferral of the replacement of some assets. This maximises the service life of assets and minimises the long run cost to customers.

AusNet Services' analysis indicates that the forecast detailed in this document will allow it to maintain the safety, quality, reliability and security of supply of prescribed transmission services. Risks such as supply outage, injury and damage to equipment, have been assessed for each major asset based on the probability of asset failure. Expressed in dollar terms, the monetised risk is expected to remain broadly constant over the period.

There are key external changes that are affecting the forecast – the value of customer reliability (VCR) and emerging trends in electricity use. Since the previous determination there have been significant reductions in the VCR and forecast demand growth, which have enabled the deferral of material replacement expenditure.

While the average age of AusNet Services' assets has continued to increase, these changes in key planning assumptions (being forecast demand and the VCR) have led to a reduction in forecast capex. However, consistent with the signals provided by the reduction in the VCR in 2014, there is expected to be an efficient small decline in network reliability. Note that for a transmission network this would not directly translate into a loss of customer supply, given that there is a level of redundancy built into the network.

The capex estimate has also been prepared in the light of the recent trends in network utilisation, the increased take up of distributed generation and the improving economics of storage technologies. Where possible, AusNet Services has sought to defer asset replacement and to seek operational solutions as an alternative to additional network development. The approach is to provide time to assess whether this is a continued long-term requirement for the assets, whist balancing the on-going requirement for a safe and reliable supply of electricity. As a direct result, investment in areas such as the Latrobe Valley has been reduced and there is minimal expenditure planned on tower structures and lines.

Stakeholder input has been sought through TRR stakeholder engagement activities. At stakeholder forums, AusNet Services has explained how capex projects are economically justified and how the VCR is used in economically justifying the projects. Stakeholders expressed views that existing assets should be used as long as it is safe to do so. When the expected impact on reliability of changes to the VCR and the consequential deferral of major projects was discussed, no strong consumer resistance to this change in reliability was heard, and the use of the reduced VCR has continued to be adopted in the planning approach.

2 Background

AusNet Services' electricity transmission network, shown in Figure 1, serves more than 2.5 million Victorian households and businesses with more than 6,500 kilometres of transmission lines which transport electricity from power generation stations to five electricity distributors and large customers.

The network is centrally located among Australia's five eastern states that form the National Energy Market (NEM), providing key connections between South Australia, New South Wales and Tasmania's electricity transmission networks. The network transferred 42,635 GW hours of energy in 2014/15 and served a peak demand of 8,626 MW.

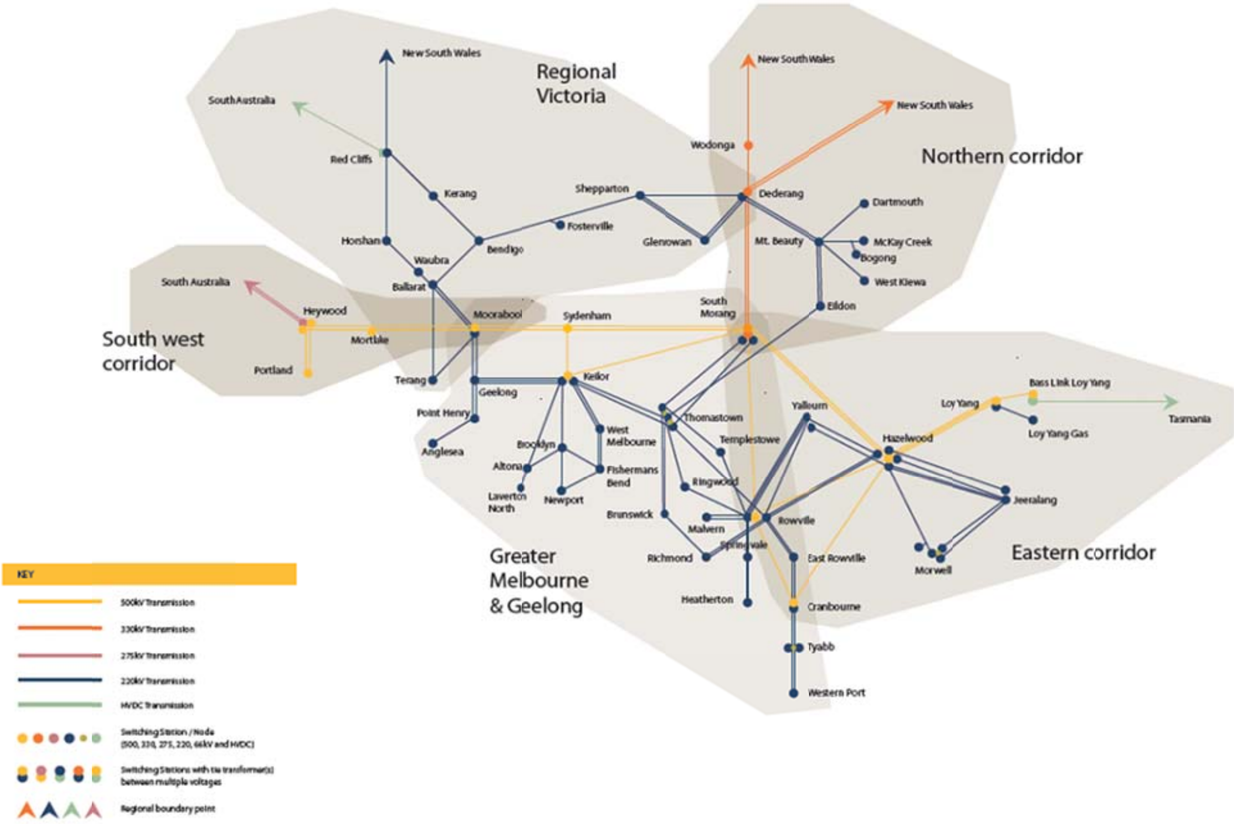

Figure 1 – The Victorian transmission Network

2.1 Victorian Planning Framework

Responsibility for planning of transmission network services in Victoria is shared by three different parties:

- Australian Energy Market Operator (AEMO) is responsible for planning the shared network[1] and procuring network support and shared network augmentations;
- AusNet Services plans asset replacements on the transmission network; and
- Transmission network customers (distribution companies, generation companies and directly-connected industrial customers) are responsible for planning and directing the augmentation of their respective transmission connection facilities.

[1] The shared transmission network is the main extra high voltage network that provides or potentially provides supply to more than a single point. This network includes all lines rated above 66 kV and main system tie transformers that operate between two voltage levels above 66 kV.

In Victoria, the transmission network planning functions are separated from the functions of ownership and operation. These arrangements differ from other states in Australia, where planning and responsibility for augmentation remains integrated with the incumbent transmission company (although independent planning oversight occurs in South Australia). The relationships between these parties, the Regulators and network users are shown in Figure 2.

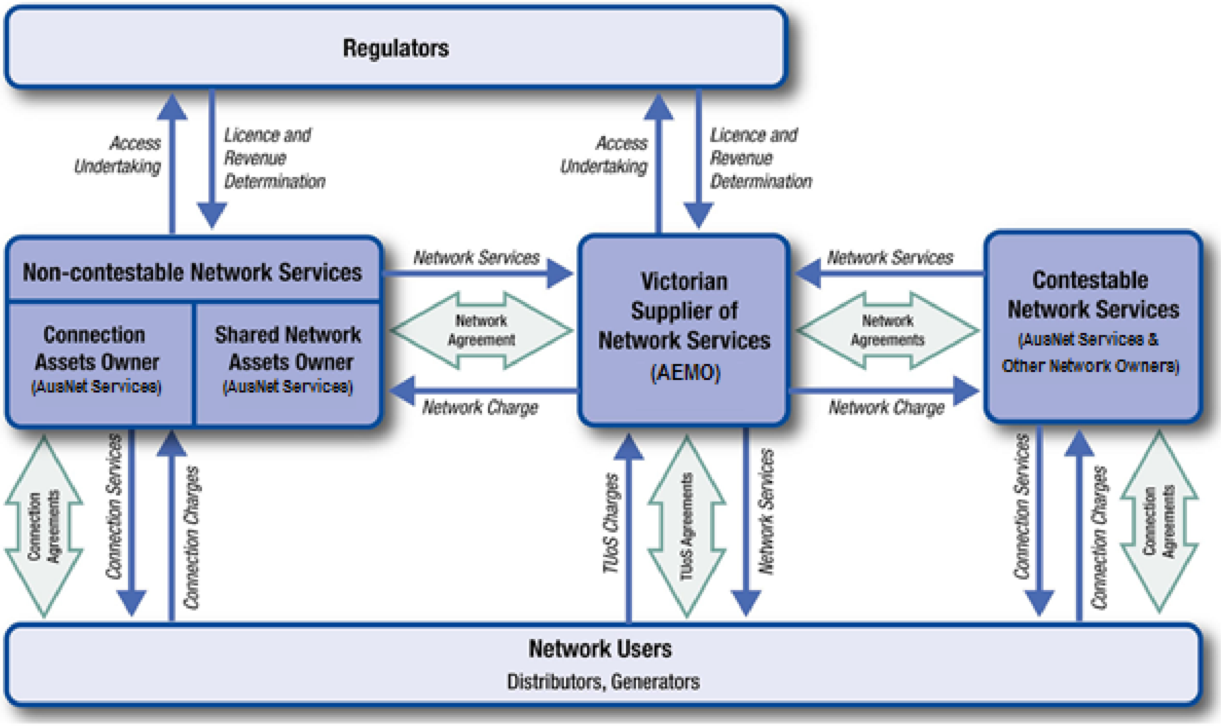

Figure 2 – Regulatory and commercial relationships

2.2 Asset Age

The Victorian transmission network experienced substantial levels of growth between 1950 and 1980 with approximately 40% of existing network assets constructed within this period. Large proportions of these assets are now approaching or have exceeded their original expected service lives. AusNet Services' asset management strategies are driven by asset condition and the consequences of asset failure. Some older assets are displaying deterioration consistent with increasing failure risk.

Table 2 below gives an overview of the current and forecast age of key assets and their expected useful lives. Most asset classes currently have less than half of their asset lives remaining. At the completion of the forthcoming regulatory period, the average remaining life of transformers will remain at 23% and circuit breakers will decrease slightly to 51%. In respect to the key lines asset categories, the structures, conductors and ground-wire percentage of remaining life will decrease significantly to 26%, 13% and 33% respectively.

Asset Type	Average Age (years)		Average Remaining Life (years)		Average Expected Life[2]	Percentage of Remaining Life	
	2015	2022	2015	2022		2015	2022
Transformers	31	31	9	9	40	23%	23%
Circuit Breakers	21	22	24	23	45	53%	51%
Structures	45	52	25	18	70	36%	26%
Conductors	45	52	15	8	60	25%	13%
Ground-wire	35	40	25	20	60	42%	33%

Table 2 – Network Age (Years)

Weighted Average Remaining Life (WARL) is a useful high level indicator of remaining network asset life. The current WARL estimate for AusNet Services is 37.1%, meaning that on average, network assets are more than two thirds through their expected service life. Due to the reduction in investment proposed for the replacement of terminal station assets over the next period, the WARL of AusNet Services' assets are expected to decrease to 36.0%. This decrease largely reflects increasing ages of transmission line conductor and structures, which make up more than half of the total network asset replacement value.

2.3 Asset Condition

AusNet Services applies a condition and risk based asset replacement approach, rather than replacing assets on the basis of service age. This method involves the use of objective condition assessments in determining the remaining service potential (RSP) of individual assets. Results of condition assessments are incorporated into quantitative risk assessments, which are an integral part of the economic decision making process.

A number of factors affect the condition of network assets; adverse factors can accelerate asset deterioration prompting replacement. Factors known to have accelerated the deterioration of assets on the Victorian network in recent years include high utilisation of primary plant coupled with high ambient operating temperatures and corrosive environmental conditions.

As discussed in the preceding section 2.1, AEMO is responsible for planning the augmentation of the shared Victorian transmission network and the five Victorian Distribution Businesses are responsible for planning and directing augmentation of the facilities that connect their distribution networks to the shared Victorian transmission network. AEMO and the Distribution Businesses use a probabilistic planning approach to optimise capital expenditure. This approach can result in power transformers being subjected to very high levels of utilisation for long periods.

These high loading levels accelerate the deterioration of power transformers, especially when combined with high ambient temperatures. High ambient temperatures and associated air conditioning loads coupled with high growth in customer connections culminated in a peak demand on the Victorian electricity transmission network of 10,603 MW in the summer of 2008-09. Peak demands have since moderated due to a combination of mild weather, lower economic activity, improved energy efficiency, increased photovoltaic generation and higher energy prices. However, this historic period of high demand has had a lasting impact on both the reliability and the condition of power transformers.

Since 2004, there have been major power transformers failures at Keilor, Morwell, Mount Beauty, Thomastown, and very recently at Ballarat terminal stations. This has driven the Victorian major transformer failure rate above the CIGRE Australia average of 0.4% per annum.

There are approximately 450 circuit breakers in poor condition, of which 74 are severely deteriorated. Notably, the GEC/AEI JW420 bulk oil units are presenting risks of an explosive failure mode due to the deteriorated condition of bushings have led to hot spots.

There are approximately 1,100 Disconnectors and earth switches in poor condition, of which 80 are severely deteriorated.

[2] Source: Table 5.2 of AusNet Services (transmission) 2014-15 – Category Analysis RIN.

Continuing investment in refurbishment and replacement of power transformers, circuit breakers, and Disconnectors and earth switches is economical over the next decade to manage failure risks based on the value of unserved energy and safety.

Transmission line assets are especially sensitive to the environments in which they operate. Assets exposed to coastal salt or industrial pollution can degrade to poor condition rapidly. Such degradation resulted in the functional failure of phase conductors on the Heywood (HYTS) to Portland (APD) 500 kV line in 2008 after just 25 years of service. Analysis of samples of the failed conductor revealed considerable corrosion at the interface between the steel core of the conductor and the inner aluminium strands.

The HYTS – APD 500 kV lines are situated close to Victoria's western coast and are exposed to coastal salt deposition. Since the functional failure in 2008, AusNet Services has replaced 15 kilometres of conductor or 50 per cent of the line between HYTS and APD. Although minimal ground wire replacements are forecast in the forthcoming regulatory period, the continuing degradation of conductors and ground wires foreshadows the need for accelerated replacements in future regulatory periods.

The condition assessment for civil infrastructure has indicated that 30 per cent of assets require refurbishment or replacement over the next decade. These assets include buildings, fire detection and suppression systems, and security fences

2.4 Network Performance

The performance of the transmission network can be linked directly to its availability and system minutes unsupplied. The availability for the 2014 calendar year was 98.96%, a result that was slightly lower compared with the previous years' performance. This was mainly due to long duration continuous outages on two transmission network elements, which were required to implement the KGTS SVC and FBTS Synchronous Condenser refurbishment works.

The System Minutes lost in 2014 were 0.585 as compared to 1.183 in 2013 and the total number of loss of supply events were five as compared to nine events in 2013.

The Key Performance Indicators since 2009 are summarised in Table 3.

Key Performance Indicator	2009	2010	2011	2012	2013	2014
Network Availability	99.02%	99.15%	99.11%	99.25%	99.18%	98.96%
System Minutes Unsupplied	40.07	0.19	0.025	2.73	1.18	0.585

Table 3 – Summary of Key Performance Indicators for the period 2009 to 2014

Overall, the transmission network performance is meeting targets; however there have been an increasing number of incidents that have had the potential to cause significant impacts.

3 Asset Management

AusNet Services' capital investment forecasts are underpinned by an asset management system that demonstrates compliance with requirements of ISO 55001 and features robust asset management practices designed to achieve customer, regulatory and shareholder expectations. Key asset management drivers are recognised and addressed as part of a dynamic process. Capital efficiency is supported by an internationally accepted approach to asset management and a proactive approach to continuous improvement of systems and processes. Asset management elements vital to developing efficient capital investment forecasts are discussed in this section.

3.1 Asset Management Drivers

AusNet Services identifies a number of factors which drive the development of prudent asset management plans as described below:

- **Network safety** – Victorian Safety Legislation requires network businesses to lodge an Electricity Safety Management Scheme (ESMS) with Energy Safe Victoria (ESV). The safety initiatives included in the transmission ESMS programs have been driven by increasing community expectations and a shift in Victoria's energy safety regime that places greater emphasis on individual company accountability for safety and targeted risk management. Formal safety assessments have been carried out for the electricity transmission network and relevant mitigating management strategies have been identified. The ESMS for the electricity transmission network was formally accepted by ESV in 2011. It is a requirement to resubmit an ESMS every five years and AusNet Services will be providing the preliminary five year revision to ESV in December 2015 with the final revision scheduled for March, 2016.
- **Network risk** – Corporate and asset related risks are key to the development of asset management plans for the transmission network. AusNet Services operates a corporate Risk Management Framework[3] utilising the principles of ISO 31000 "Risk management – Guidelines on principles and implementation of risk management", to assess a range of business risks. Corporate risks and control measures are registered using a risk management information system, CURA. Asset risks are quantified through the application of Reliability Centred Maintenance (RCM) techniques. Asset condition data collected during scheduled maintenance tasks is used to determine dynamic time based probability of failures and percentage of remaining service potential (RSP) of each asset. RCM models include the consequence of failure for each major asset and provide risk profiles for each asset category which are used to establish optimised maintenance and asset replacement plans.
- **Performance** – Network performance is recognised as a key driver for asset investment decisions. The performance of the transmission network is monitored against the service target performance incentive scheme (STPIS). Under the scheme, network performance is measured against four inter-related elements; reliability, plant availability, supply security and supply quality.
- **Sustainability** –Aside from emission management, AusNet Services focuses on the protection of the immediate environment in which it operates through its AS/NZS ISO 14001 certified environmental management systems. The environmental management system is the principle tool through which AusNet Services identifies environmental risks, develops and implements solutions and monitors success in controlling such risks.
- **Augmentation** – Network augmentation investments are driven by growth in electricity consumption and demand, and rising fault levels. AEMO and Victorian DNSPs are responsible for the planning and justification of transmission network augmentation projects. AusNet Services works closely with AEMO and DNSPs in planning future asset replacement programs ensuring that alignment with planned augmentation works is optimised.

[3] RM 001-2006 Risk Management Framework.

- **Advances in technology** – The nature of the energy sector will change fundamentally over the next decade, responding to community expectations of safety and reliability, climatic change and emerging technologies. Advances in technology are facilitating new large scale renewable electricity generation techniques and more efficient small-scale embedded generation solutions. At the same time the use of electricity is changing through improved energy efficiency, energy storage, and the introduction of electric vehicles. Integration of these new sources of generation presents new challenges to the transmission network.

3.2 Asset Management System

Until April 2014, AusNet Services' asset management system conformed to the requirements of the British Standards Institute's Publicly Available Specification PAS 55-1:2008. This asset management system now conforms to the requirements of ISO 55001. Conformity with this standard means that AusNet Services' asset management system meets contemporary asset management standards, comprehensively covers all aspects of asset management, and incorporates formal processes for continuous improvement.

The scope of this asset management system includes the management functions, asset information systems and the physical assets which form the following regulated energy networks owned and operated by AusNet Services within the state of Victoria:

- Electricity transmission network;
- Electricity distribution network; and
- Gas distribution network.

The asset management system includes the following functions for each network:

- Creation and acquisition of assets;
- Commissioning of assets;
- Operation of the network;
- Inspection and maintenance;
- Repair, refurbishment and replacement of assets; and
- Decommissioning, removal and disposal of assets

4 Historic Major Capital Works

Table 4 below, summarises a selection of major projects and programs from the current regulatory period. Historic capital expenditure has been categorised as major projects, asset replacement and safety improvement programs.

Project Category	Project	Description
Major projects	Terminal station refurbishment	- **Glenrowan Terminal Station (GNTS):** Replace one 220/66 kV transformer, selected 220 kV and 66 kV CBs, and install protection and CB management systems - **Geelong Terminal Station (GTS):** Replace two 220/66 kV transformers, and selected 66 kV CBs. - **Rowville Terminal Station (ROTS):** Replace seven 220 kV CBs, and install protection and CB management systems. - **Dederang Terminal Station (DDTS):** Replace one 330/220 kV transformer. - **Ringwood Terminal Station (RWTS):** Replace nine 220 kV CBs and CB management systems. - **Yallourn Power Station (YPS):** Replace selected 220 kV CBs, and high risk CTs.
Asset replacement program	Tower / Conductor replacements	Selective upgrade of EHV towers at high risk sites on the SMTS-DDTS No.1 and 2 330 kV lines. Transmission conductor replacement – 80km of ground-wire and conductor
Safety improvement program	Replacement of insulators and fittings	Replace approximately 4,400 poor condition insulators and fittings on selected lines.
Safety improvement program	Fall restraints on towers	Installed fall arrest systems to comply with a Work Safe agreement. This work will continue into the next regulatory period.
Safety improvement program	Installation of station security fences	Fences were augmented to prevent unauthorised access at multiple locations to improve security in line with increasing security threats to essential infrastructure.

Table 4 – Major projects and programs to be completed in the current regulatory period

5 Long Term Capital Works Forecast

In the longer term, and acknowledging deteriorating condition in a significant proportion of assets installed more than 50 years ago, AusNet Services' forecasts continued expenditure on major station refurbishments over the next two to three regulatory periods. This is driven by expected replacements in major station rebuild projects, consistent with the timing of the replacement schedule set out in the 2015 Victorian regulatory submission. As shown below in Figure 3[4], spending in the current and forecast period is focussed on metropolitan stations and generator switching connection stations.

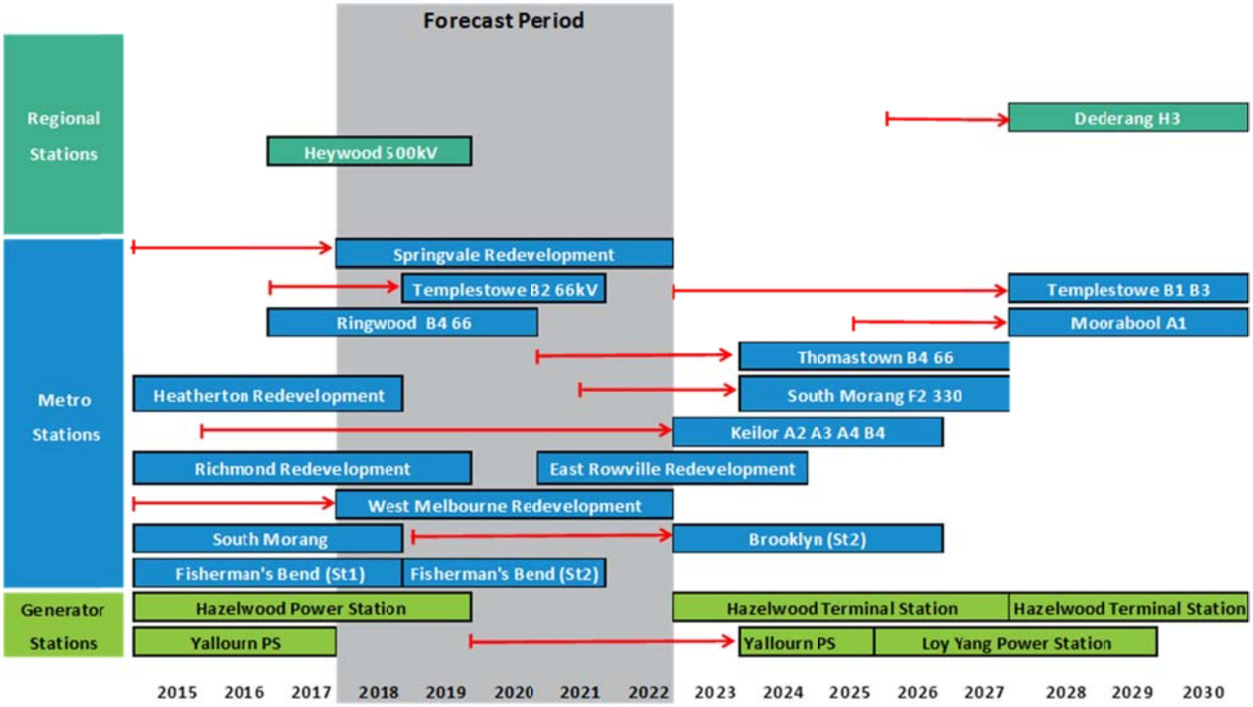

Figure 3 – Timeline of station rebuilds

Further significant investment will be required to replace line conductors and towers in the longer term. This expectation is driven by the fact that currently there are high volumes of line assets with similar service age and condition profiles. The condition of large proportions of these asset classes are expected to progressively deteriorate simultaneously triggering large scale replacement programs which will require careful integration with any augmentation needs of AEMO.

4 The red lines show project deferral since 2013 resulting primarily from lower VCR and lower forecast demand.

6 Capital Expenditure Forecasts Methodology

In accordance with Schedule 6A.1.1, this section describes the methodology used for developing the capex forecast, and the key assumptions that underlie the forecasts. The capex forecasts presented in this chapter reflect, and are consistent with the implementation and efficient execution of this methodology and AusNet Services' Asset Management Strategy[5].

The overall forecasting approach is based on a bottom-up build of individual project costs summated to form an initial total forecast. Cost escalation or de-escalation is then applied across the entire suite of forecast projects (according to their labour and material profile) to account for expected changes in input costs. Finally, the expected savings from continuous capital project management and governance (capex efficiency) is applied across the entire program of works to provide the final forecast. The overall forecasting methodology is illustrated below in Figure 4.

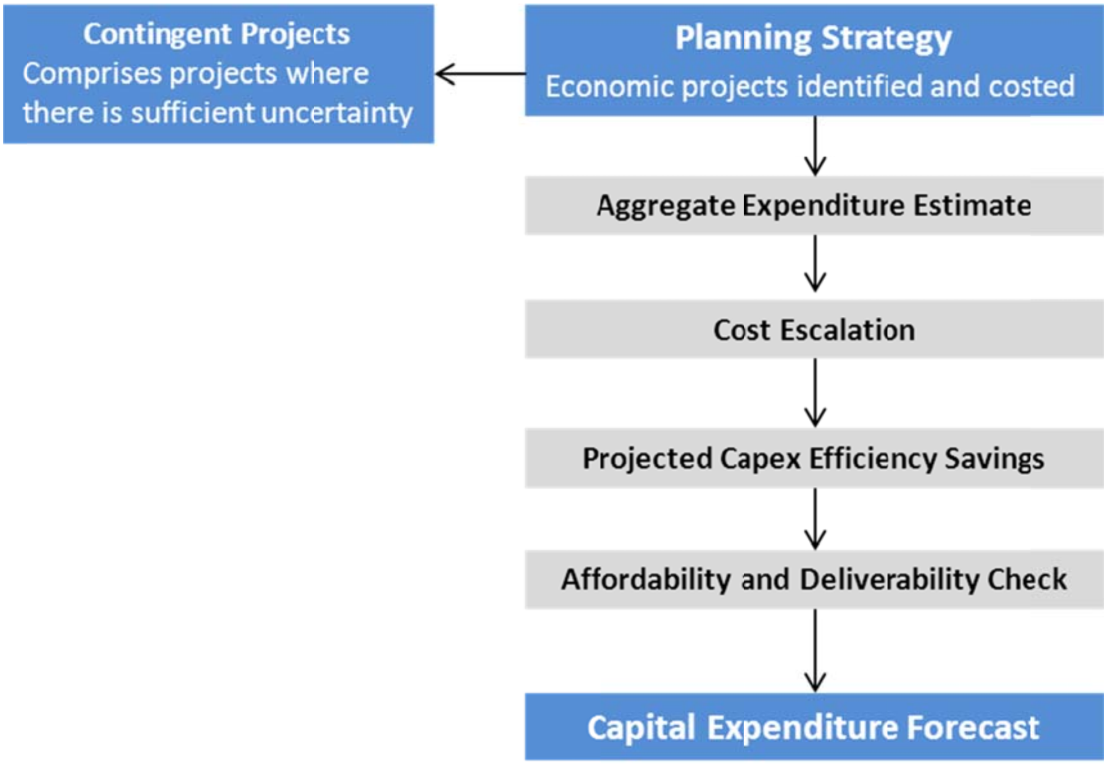

Figure 4 – Capital Expenditure Forecasting Process

The major stages of the bottom-up build are outlined in detail in Section 6.1.

[5] AMS 10-01 Transmission Network Asset Management Strategy.

6.1 Bottom-up Forecasting

The bottom up capital expenditure forecast is estimated by summing-up expenditure across all the programs and projects. This involves identifying, scoping and costing every project and program over the entire regulatory period, and then estimating the timing of expenditure on each project and the impact of escalators. This multi-stage process is shown below in Figure 5.

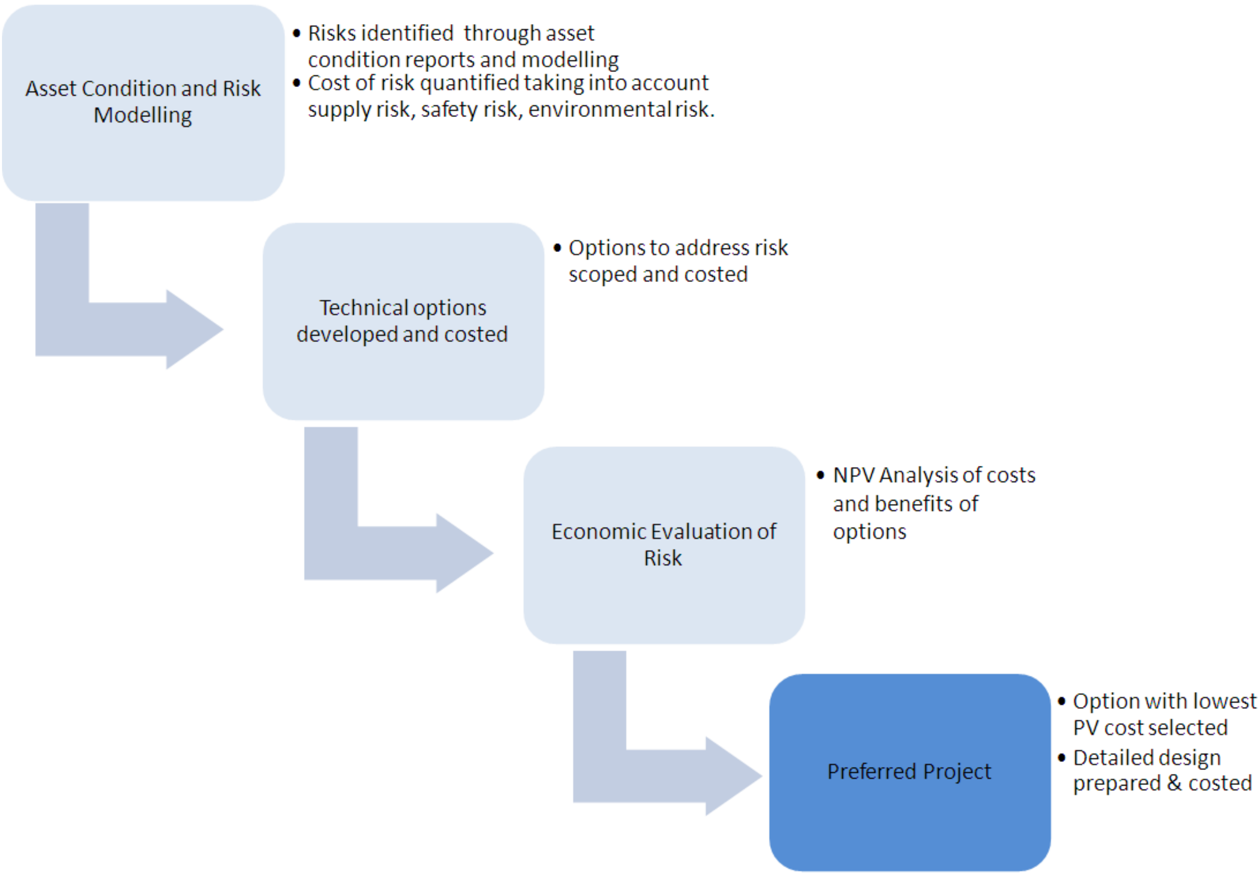

Figure 5 – Capital Expenditure Forecasting Methodology

6.1.1 Condition Based Risk Modelling

Assets are initially prioritised for economic evaluation using condition based quantitative risk assessments. Risk models are developed using objective asset condition assessments, quantified failure consequences and Reliability Centred Maintenance (RCM) techniques.

A wide range of methods and techniques are used to assess the condition of all major asset categories as described in Table 5.

Asset condition data informs the definition of remaining service potential (RSP) which is used to establish dynamic time-based probability of failures for each asset. Probabilities of failure are validated by comparison against historical failure data for each asset category.

Asset Type	Condition Assessment Methods
Transformers	- Offline electrical testing - Dissolved Gas Analysis
Circuit Breakers	- Gas and oil sampling - Offline electrical testing - SF_6 analysis
Switchgear	- Visual inspection for corrosion - Thermal imaging
Conductors	- Visual inspection for corrosion - Smart Aerial Image Processing (SAIP)
Insulators	- Visual inspection for degradation
Power Cables	- Visual inspection of cable joints for signs of corrosion

Table 5 – Condition Assessment Methods

RCM involves the assignment of functions and functional failures to individual network assets. Failure Mode Effect Criticality Analysis (FMECA) of historical asset failure data determines typical root causes of functional failures and quantifies the effects or consequences these have on key performance measures including network safety, reliability and availability. Consequences of asset failures are expressed in monetary terms for each performance measure and summed to represent total consequence cost of failure for each asset.

Consequence costs of asset failure are then multiplied by the condition based probabilities to quantify the overall cost of failure for each asset as illustrated in Figure 6. The probability weighted cost of failure is referred to as the “risk cost”.

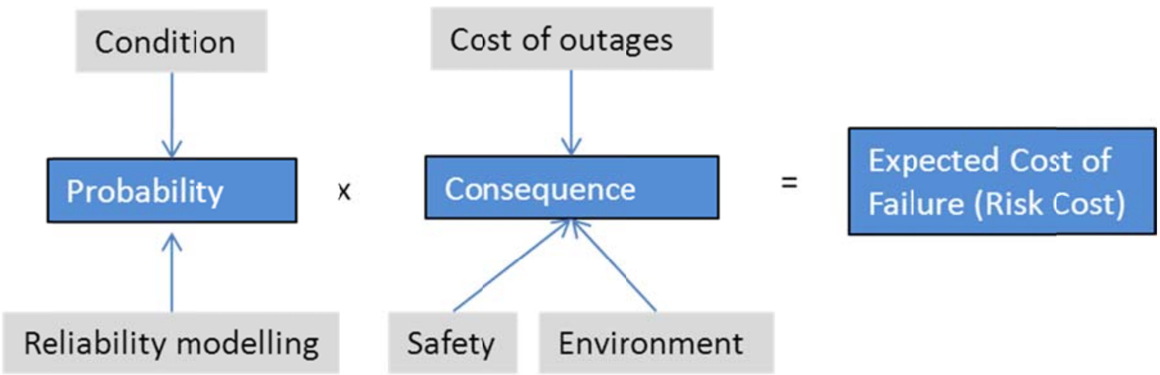

Figure 6 – Quantifying Cost of Asset Failure

6.1.2 Estimated Costs of Technical Options

RCM models output the risk cost of failure for each individual asset, technical options are then developed as part of an engineering assessment to address those assets where the risk cost exceeds the generic cost of funding remedial action. Models assign risk rankings which, assist with prioritising assets for engineering assessment. A range of deliverable options to address the risk are identified and scoped including options involving refurbishment of assets. The shared network augmentation needs of AEMO and the connection asset augmentation needs of the distribution businesses over the planning period are taken into account in the scoping and scheduling of these asset replacement options. There is also analysis undertaken across projects to identify the potential efficiencies to be achieved through the coordination of the scope and timing of different projects. For example, some minor replacement work may be included in a major replacement project to attain synergies in project design, project management and project establishment costs. This reduces the cost of minor replacement work and ensures that new assets are configured to function reliably with other assets, as an integrated system. Project cost estimates are then provided for each technically feasible option.

6.1.3 Economic Evaluation of Technical Options

Following the development of project cost estimates for each technically feasible option, economic evaluations are performed to determine the preferred option. Net Present Value (NPV) models facilitate the economic evaluation. NPV studies analyse the costs and benefits of each option, with the aim of identifying the most economic option (the preferred option). The economic timing of the selected option is established by comparing the annualised total cost of the selected option with the annual incremental benefits (that is, reduced risk or avoided cost of failure) it is expected to deliver. Under this evaluation approach, the economic timing is identified as the point in time at which the annual incremental benefits just exceed the annualised cost.

Sensitivity studies around the discount rate, asset failure rate and demand growth scenarios are conducted to test the robustness of the economic evaluation. This is a crucial step in ensuring replacement investments are economic under a range of reasonable scenarios.

AusNet Services also explores the potential for efficiencies to be derived by undertaking large complex projects in discrete stages. Under this approach, the highest asset failure risks are identified so that these can be addressed in a timely fashion, while the timing of lower-risk project components may be deferred to assist with delivery of the overall capital program.

Overall, the approach is consistent with the annual Victorian transmission plans published by AEMO (Victorian Annual Planning Report) and the Distribution Businesses' (Transmission Connection Planning Report and Distribution Annual Planning Reports). It is also consistent with the principles underpinning the regulatory investment test.

6.1.4 Project Cost and Timing

A detailed project scope and cost estimate is prepared for the most economic option. This is done using a detailed technical scope of works and current unit costs for installing or replacing assets. The cost estimate is the most likely cost (the P50) of the project and assumes the scope of work will not change during the detailed design and construction phases. The estimate does not capture possible changes in unit costs (discussed in the next section). However, the expected cost of various project contingencies, are estimated using Monte Carlo analysis.

In large complex projects a greater proportion of expenditure occurs toward the middle of a project on equipment procurement and construction contracts. Smaller proportions are spent on design at the beginning and on commissioning toward the end of the project. This expenditure profile forms characteristic S-curves, as shown below in Figure 7. For the forecast capital expenditure program average S-curves have been calculated, based on historic project expenditure, and allocated expenditure on planned projects accordingly.

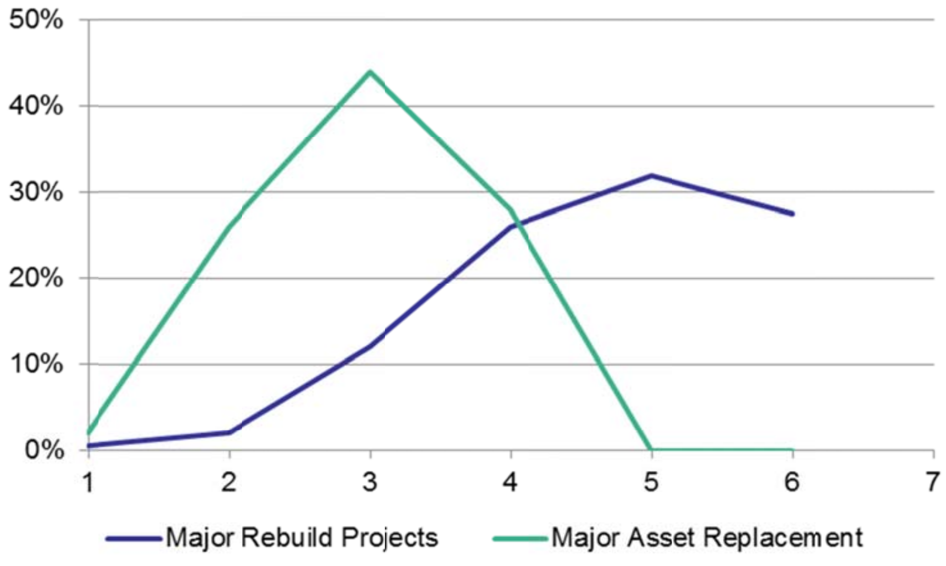

Figure 7 – Project Spend Profiles (S-Curves)

An important step in determining project timing is program optimisation. During this step the capital program, as a whole, is considered and optimised to facilitate timely delivery. As a result, the timing of some individual projects may be adjusted to optimise the overall program. This program optimisation facilitates a smooth demand for capital raising, major equipment procurement, detailed design services and project management and construction services. The smoothing of resource demands produces a lower overall cost of capital investment.

6.1.5 Real cost escalators

The price of several project inputs is expected to increase over the regulatory period, in excess of CPI. To take these changes into account, project costs are broken down into labour and materials escalators. Broadly these are:

- **Internal labour:** The cost of using AusNet Services' staff and labour hire on capital projects
- **External labour:** The cost of external contractors on capital projects
- **Asset "Materials" escalators:** This includes all other costs and is divided into the following ten different sub-categories: secondary equipment, switchgear, transformers, reactive equipment, lines and towers, establishment, communications, non-network, land and easements.

For each category, AusNet Services has commissioned an expert forecast of real price changes relative to the base year. These escalators are then applied to the appropriate expenditure category for each project to calculate the escalated project cost. Once this is done, costs are simply summed across all projects.

6.1.6 Improvements in capital efficiency

AusNet Services is constantly looking for ways to improve capital efficiency. This includes independent Post Implementation Reviews (PIR) of completed projects and programs and continual improvement in asset management practices and systems. All improvements to date have been included in the capital expenditure forecast. However some small further improvements are expected to occur over the next period of approximately 0.89%[6]. This has been factored into the overall forecast.

[6] See Revenue Proposal Chapter 4 – Capital Expenditure Chapter for more details.

7 Expected Benefits of Capital Expenditure

This section provides an overview of the key benefits of AusNet Services' forecast capital investment over the regulatory period. The aggregate outcomes of the capital program are consistent with those identified in the detailed underlying project justifications. The key outcomes are outlined below.

7.1 Safety and Safety Compliance

AusNet Services must comply with the requirements of the Electricity Safety Act (1998) and the Occupational Health and Safety Act (2004).

The Electricity Safety Act requires AusNet Services to operate its electricity transmission network to minimise, as far as practicable, hazards to the safety of any person. Under the Occupational Health and Safety Act it is a requirement, as far as is reasonably practicable, to maintain for employees a working environment that is safe and without risks to health.

When evaluating alternative remediation options AusNet Services must have regard to the likelihood and harm and what is known or should be known about the safety hazards. Ways to eliminate or mitigate hazards and the availability and suitability of ways to eliminate or mitigate safety hazards must be considered. AusNet Services is further obliged to have regard to the cost of removing or mitigating the safety hazard or risk. In economic terms "reasonably practicable" requires safety hazards to be addressed up until the point that the costs of remediation become grossly disproportionate to the benefits.

AusNet Services maintains an accepted Electricity Safety Management Scheme (ESMS) as required under the *Electricity Safety Act 1998* and in compliance with the *Electricity Safety (Management) Regulations 2010*. The ESMS forms an outcome based regulatory framework against which Energy Safe Victoria (ESV) maintains regular audits to monitor compliance. Energy Safe Victoria endorsed AusNet Services' ESMS[7] for the transmission network in March 2011.

Endorsement of AusNet Services' ESMS recognises adherence to obligations of the act in developing prudent asset management practices including the development and implementation of capital programs. The use of formal safety assessments, in particular, is an ESMS obligation that has influenced the scopes of projects included in the capital forecast that are primarily driven by safety compliance.

Many of the safety improvements delivered by the capex program will arise incidentally as a result of replacing old equipment with new, safer equipment and through the application of modern, safer station design standards. Other improvements will result directly from projects aimed at improving safety (or safety compliance). A high level summary of the safety outcomes provided by the forecast capital works program is shown in Table 6.

Project or Type of Project	Condition Assessment Methods
Tower Strengthening	- Reduced risk of public injury or death from a tower collapse
Cable fall arrests systems	- Reduced risk of death or injury to an employee from falling
Transformer replacement	- Reduced risk of death or injury from an explosion or fire
Indoor switchgear	- Reduced risk of electrocution
Conductor replacement	- Reduced risk of conductor drop causing injury or death
Site security	- Reduced risk of injury or death resulting from unauthorised persons approaching electrical equipment
Insulator replacement	- Reduced risk of conductor drop causing injury or death
Circuit breaker replacement	- Reduced risk of death or injury from an explosive failure of circuit breaker bushings or oil fire
Asbestos removal	- Reduced risk of injury or death from exposure to asbestos containing materials in accessible workplace

Table 6 – Safety Outcomes of Capital Program

[7] ESMS 20-01 Electricity Safety Management Scheme, Overview for Electricity Transmission Network.

7.2 Network Risk and Reliability

The impact of the forecast asset replacement expenditure and an assessment of risk are shown in Table 7.

Asset Type	Program	Risk Assessment
Tower	Reinforce 48 towers and install fall arrest systems on approximately 3,300 towers.	Risk reduction obtained by strengthening towers and reducing the likelihood and consequence of a fall as less than a quarter of towers remain without fall arrest systems
Conductor and Ground Wire	Replace approximately 220 km of groundwire with150 km of standard groundwire and 70 km of OPGW.	Marginal increase in conductor risk but maintains risk of ground-wire population
Circuit Breaker	Replace approximately 150 circuit breakers through proposed station rebuilds and targeted programs.	Maintains Risk
Instrument Transformer	Replace approximately 100 instrument transformers through proposed station rebuilds and targeted programs.	Maintains Risk
Disconnectors and Earth Switches	Replace / refurbish approximately 300 deteriorated Disconnectors and Earth Switches.	Maintains Risk
Power Transformer	Replace 10 power transformers, 22 bushings and complete various asset management activities to extend the life of 37 transformers.	Maintains Risk

Table 7 – Asset Type Risk Assessment

Risk models that define the monetised risk profiles for the major asset classes are used to assess asset failure risk. Objective asset condition assessments and historic failure consequences are used as inputs in the risk models. The total risk resulting from the operation of the transmission network can be estimated by summing the various risk costs such as safety, supply, environmental, and collateral damage risk from these risk models. These monetised risk profiles provide a dynamic view of changes in asset failure risk considering past and future capital investment levels.

Asset replacement over the forthcoming regulatory period will largely be driven by the risk associated with power transformer, circuit breaker and instrument transformer failures.

The proposed terminal station asset replacement program has been based on economic planning criteria and will maintain risk levels at present levels for the planning period until 2022. The risk associated with transmission lines will marginally increase as the overall condition of large parts of the transmission line conductor and structure fleet continues to decline.

7.3 Environment

Some primary plant equipment can present environmental risks especially those power transformers and circuit breakers containing large volumes of insulating oils. Typically, these risks arise from oil leaking from transformers and circuit breakers, pollution caused by a fire or from uncontrolled release of SF_6 gas insulants. Station rebuild works over the past regulatory periods have replaced many 220 kV bulk oil circuit breakers and several deteriorated power transformers which will benefit the environment through the reduction of risks of spills. However there are 28 220 kV and approximately 200 66 kV and 22 kV bulk oil breakers remaining. Additional circuit breakers will be replaced as part of asset replacement program targeting high failure risk bulk oil units.

AusNet Services will continue the installation of oil containment and water treatment systems at stations not scheduled for refurbishment. These water treatment systems will ensure compliance with Environmental Protection Agency (EPA) guidelines before the conclusion of the forthcoming regulatory period. AusNet Services' capital forecast includes refurbishment of fire deluge systems installed above power transformers. Deluge systems operate to extinguish fires mitigating the impact to the environment.

A program to remove asbestos containing materials from accessible workplace asbestos by 2025 will reduce critical safety risks in the forthcoming regulatory period. If left unaddressed, asbestos has proven to be life-threatening. As part of AusNet Services' commitment to making its workplaces safe for all staff and the public, the company has initiated an asbestos removal program. As part of this program, asbestos audits have been performed at all terminal stations identifying nine sites which require asbestos removal. Asbestos will be safely removed from these sites over the forthcoming regulatory period as part of this forecast capital work program

7.4 Enhancing future capital expenditure programs

AusNet Services is committed to optimising the efficiency of future capital expenditure by identifying further improvements that can be made to the processes in which capital programs are developed and implemented. Enhancement of current condition monitoring techniques provides opportunities to prevent asset failures whilst optimising the timing of future capital investment by avoiding the premature replacement of network assets. This opportunity is especially pertinent to lines assets and the installation of continuous online monitoring systems on older power transformers. Furthermore, sustained collaboration with AEMO and the DNSP's will ensure careful co-ordination of augmentation and asset replacement projects allowing capital works programs to be delivered as efficiently as possible.

7.4.1 Coordinating future development

In Victoria, AEMO is responsible for network planning and augmentation, and AusNet Services is responsible for maintaining the network assets. However, these two activities need to be carefully coordinated to ensure that the two capital programs are aligned. Specifically, any significant asset replacements must consider the longer term shared network and connection network development plans to ensure individual decisions do not compromise security of supply or impede economic future capacity augmentation. Joint planning with AEMO and the DNSPs allows for augmentation projects to be undertaken in conjunction with major asset replacement projects when it is economic and either AEMO or the DNSP direct AusNet Services to undertake the augmentation project.

7.4.2 Enhancing condition assessments

As discussed in Section 6.1.1 asset condition data collected during scheduled maintenance tasks and specific assessment testing has become a key input to risk models which focus the development of asset replacement programs. The accuracy of the condition data acquired can impact upon the scope and timing of asset replacement programs.

Condition grading of transmission ACSR line conductors can be difficult to perform visually as the corrosion starts and progresses internally at the interface between the steel core of the conductor and the inner aluminium strands before it is visible upon the outer aluminium strands. Traditional practices for assessing the condition of transmission line ACSR conductors require the asset inspector to visually inspect the conductor using image stabilised binoculars. These methods are basic and are unsuitable for accurately assessing large populations of deteriorating conductor which may require replacement over the next 20 years.

AusNet Services has successfully trialled several new technologies, such as overhead line Corrosion monitoring (CORMON) and Smart Aerial Image Processing (SAIP), which offer more accurate assessment of conductor condition. These more accurate condition assessment techniques will be expanded in the forthcoming regulatory period to better inform the development of economic line replacement programs. These new technologies will require a step change in operating costs. However, the data captured by these technologies will improve the targeting of future risk based conductor replacement programs whilst simultaneously preventing conductor failure incidents similar to that on the HYTS-APD 500 kV line in 2008.

8 Capital Expenditure Forecasts

All expenditure forecasts in this section are expressed in $2015 P50 direct costs only. The forecast costs do not include overheads or cost escalation. AusNet Services regulated capital expenditure authority process requires main Board approval for projects which cost in excess of $50 million, approval from the Managing Director for projects which cost up to $50 million, approval from the General Manager of Asset Management, Service Delivery and Finance for projects which cost up to $5 million, approval from the General Manager of Select Solutions and Information and Communication Technology for projects which cost up to $2 million and approval from all other relevant General Managers for projects which cost up to $1 million.

As part of the regulatory submission, information is requested in Schedule 1 of the Regulatory Information Notice (RIN) for the forecast period 1 April 2017 to 31 March 2022. More information is available in Appendix A: RIN Methodology

8.1 Current Projects

AusNet Services has a number of large committed projects that are currently in the construction phase and are discussed in this section. These projects were commenced prior to FY17/18 and are on-going projects on which expenditure has occurred and will continue to occur in the forecast regulatory period. The forecast costs for these have been informed by the most recent, detailed cost-to-complete estimates. The costs are in accordance with approved expenditure but some escalation may have occurred over the period of the project.

8.1.1 SMTS H2 Transformer replacement XC19

South Morang Terminal Station is located approximately 23km north-east of Melbourne. It consists of four switchyards: 500 kV, 330 kV, 220 kV and 66 kV. It has two 700MVA 330/220 kV single phase banks of transformers between the 330 kV and 220 kV switchyards that form part of the interconnector between New South Wales and Victoria. These six single phase transformers form the H1 and H2 transformer banks and were installed in the 1960's. They are in deteriorated condition.

In 2013 a business case was approved for the first of a two staged replacement program, replacing the H2 transformer. This project has commenced and will replace the three 330/220 kV single-phase H transformers with a new 700 MVA 330/220 kV transformer bank of three single-phase units and install a new 330 kV switch bay for the connection of the new transformer. Work to replace the transformer commenced in 2014 and the project is scheduled to be completed in 2018/19. The table below provides the forecast expenditure for the review period.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	16,207	816	0	0	0	17,023

Table 8 – Expenditure on the SMTS H2 Transformer Replacement

Scope of works:

- Install a new 700 MVA 330/220 kV transformer bank of three single-phase units
- Install new 330 kV switch bay for the new transformer
- Retain the existing two H transformers. One as an in-service unit and the other as a cold spare on site

Benefits and investment drivers:

- Reliability (primary project justification)
- Safety
- Environmental
- Reduced risk of plant collateral damage
- Reduced maintenance

Related documents:

- Planning Report Project XC19 – South Morang Terminal Station H1 and H2 Transformer Replacement
- AMS 10-67 Power Transformers and Oil Filled Reactors

8.1.2 HWPS 220 kV Switchyard Redevelopment Stage 4 XC 28

The HWPS 220 kV switchyard was constructed in the mid-1960s and, with the exception of those assets that have been replaced in Stage 1 or 2 of this extended re-development program, the majority of the assets are more than 45 years of age. The switchyard accommodates thirty-three 220 kV circuit breakers and six interconnecting busbars.

The switchyard redevelopment is in its final stage. The current project replaces seven bulk oil 220 kV circuit breakers, nine current transformers, nine voltage transformers and a number of disconnect switches. When it is completed, the replacement of all assets at HWPS will have been achieved.

The business case for this stage of the project was approved in February 2015 and completion is scheduled for 2019. The table below provides the forecast expenditure for the review period.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	7,713	3,650	0	0	0	11,363

Table 9 – Expenditure on the HWPS 220 kV Switchyard Redevelopment Stage 4

Scope of works:

- Replace seven 220 kV JW420 Bulk Oil breakers
- Replace nine 220 kV current transformers
- Replace nine 220 kV voltage transformers
- Replace 39 Strange disconnectors and earth switches

Benefits and investment drivers:

- Reliability (primary project justification)
- Safety
- Environmental
- Reduced risk of plant collateral damage
- Reduced maintenance

Related documents:

- Planning Report – Project XC28 HWPS Circuit Breaker Replacement Stage 4
- AMS 10-54 Circuit Breakers
- AMS 10-64 Instrument Transformers
- AMS 10-59 Disconnectors and Earth Switches

8.1.3 FBTS Refurbishment XC17

Fisherman's Bend Terminal Station (FBTS) is located approximately 3 km south-west of Melbourne's CBD and is the main source of power supply for Docklands and Southbank, Port Melbourne, Fisherman's Bend, Albert Park, Middle Park and St Kilda West.

Established in late 1960s, the primary and secondary assets at FBTS have deteriorated and are at an increasing risk of failure and experiencing inefficient operation and incurring higher maintenance costs. Economic studies support replacement of the assets taking into account the probability of failure and the resultant costs. This project is to replace the B1 transformer with a 150 MVA 220/66 kV transformer and also those 220kV and 66kV circuit breakers with the most critical risk of failure.

A business case to proceed with this project was approved in November 2014 and work commenced in 2015. The table below provides the forecast expenditure for the review period.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	3,438	0	0	0	0	3,438

Table 10 – Expenditure on the FBTS Transformer and Circuit Breaker Replacement

Scope of works:

- Replace the B1 transformer with a 150 MVA 220/66 kV transformer
- Replace one off 220 kV circuit breakers
- Replace 6 off 66 kV current transformers
- Replace 12 off 66 kV circuit breakers

Benefits and investment drivers:

- Reliability (primary project justification)
- Safety
- Environmental
- Reduced maintenance

Related documents:

- Planning Report Project XC17 Fisherman's Bend Terminal Station Refurbishment
- AMS 10-67 Power Transformers and Oil Filled Reactors
- AMS 10-54 Circuit Breakers

8.1.4 RTS Redevelopment XA09

Richmond Terminal Station (RTS) provides supply to the eastern Central Business District and the inner east and south-east suburban areas of metropolitan Melbourne. Three of the four existing transformers have been assessed as being in poor condition and presenting some of the highest risks of failure of any transformers in the Victorian electricity transmission network. The RTS 220 kV, 66 kV and 22 kV switchgear also present critical supply risks due to their poor and deteriorating condition.

The project received approval from the Board in 2010; however, the project scope was revised to improve the site visual amenity following experiences with the Brunswick Terminal Station (BTS) augmentation project. The revised project was approved by the board in May 2012.

Work on the RTS rebuild project commenced in 2011/12 and completion is now expected in 2018/19. The table below provides the forecast expenditure for the review period.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	11,437	1,094	0	0	0	12,531

Table 11 – Expenditure on the RTS Redevelopment Project.

Scope of works:

- Rebuilding 22 kV, 66 kV and 220 kV switchyards using indoor GIS technology
- Replacing four 150 MVA 220/66 kV transformers with three 225 MVA 220/66 kV transformers
- Architecturally treating the buildings, creating buffer zones around the site and landscaping

Benefits and investment drivers:

- Reliability (primary project justification)

- Improved safety
- Creating necessary space for future developments on site
- Reduced environmental risk
- Improved visual amenity and meeting local government objectives

Related documents:

- Business Case Application for Approval: XA09 Richmond Terminal Station (RTS) redevelopment project (29 May 2012)
- Board paper: Richmond Terminal Station Redevelopment Project (15 May 2012)

8.1.5 HTS Rebuild XB59

Heatherton Terminal Station (HTS) is the main source of supply for much of bayside Melbourne, supplying from Brighton in the north to Edithvale in the south.

HTS was commissioned in 1964, and the primary and secondary assets at the station have deteriorated and are nearing end of life. The possible failure of a 220/66 kV transformer, 220 kV circuit breakers or 66 kV circuit breakers poses an unacceptably high risk to security of supply for bayside Melbourne. The high and increasing failure risks and the costs associated with inefficient operation and more frequent maintenance justify a rebuild of the station.

Business case approval for the project was obtained in September 2014 and the project commenced the following year. The table below provides the forecast expenditure for the review period.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	3,640	0	0	0	0	3,640

Table 12 – Expenditure on the HTS Rebuild Project

Scope of works:

- Replace three 150 MVA 220/66 kV transformers
- Replace the 220 kV switchgear and reconfigure the transformer and line connections
- Upgrade the 220 kV busbars
- Replace 66 kV switchgear
- Upgrade the 66 kV busbars
- Replace secondary systems

Benefits and investment drivers:

- Reliability (primary project justification)
- Health and safety
- Reduced risk of plant collateral damage from explosive failure
- Reduced maintenance

Related documents:

- Planning Report Project XB59 –Heatherton Terminal Station Redevelopment
- Board Paper - Heatherton Terminal Station (13 Sept 2012)
- Business Case Application for Approval: XB59 HTS Redevelopment Project
- AMS 10-67 Power Transformers and Oil Filled Reactors
- AMS 10-64 Instrument Transformers
- AMS 10-54 Circuit Breakers

8.2 Major Projects – Station Rebuilding and Refurbishment Program

8.2.1 West Melbourne Rebuild (XA14)

Summary:

West Melbourne Terminal Station (WMTS) is one of three terminal stations in Melbourne supplying the CBD. It also supplies the surrounding residential, commercial and industrial areas to the west of the city. It sits on a relatively small site bounded on all sides so expansion at this site is constrained by limited space.

Much of the existing equipment was installed in 1964, has deteriorated and is now at a high and increasing risk of failure. The redevelopment of WMTS is driven by reliability considerations, the load criticality of the CBD and asset performance, particularly as several faults have already been experienced on the site and manufacturers have withdrawn further support for many of the circuit breakers now assessed as at risk. CitiPower is relying on completion of this project to deliver a reliable and secure supply to the CBD. The AusNet Services Board has approved the rebuild of WMTS to manage this supply risk to the CBD and inner Melbourne areas.

The planned rebuild will replace end-of-life assets with modern, safe and more compact equivalents. The station will also be re-designed so that it is able to accommodate future capacity expansions planned by AEMO and CitiPower.

As a committed project, work commenced on the WMTS rebuild in 2012/13 however a number of exogenous factors have contributed to project delays and a review of the economic timing and design of the redevelopment. Costs were approved for the current regulatory period assuming the rebuild would involve the use of GIS 220 kV switchgear. Following the cancellation of the East West Link project and other factors which eased space constraints at the site, a redesign of the project has been undertaken to deliver a lower cost redevelopment utilising air insulated switchgear.

The table below sets out the forecast capex requirements for WMTS. These have been informed by the most recent, detailed cost forecasts for similar works at RTS.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	20,885	21,896	25,995	16,000	7,148	91,924

Table 13 – Expenditure on the West Melbourne Rebuild

Scope of works:

- Replace 22 kV, 66 kV and 220 kV switchyards with outdoor AIS switchgear
- Replace B1, B2 and B4 220/66 kV transformers
- Establish a new control room in the existing control building
- Establish new AC and DC supplies
- Install a new oil separation and water treatment facility
- Replace protection and control systems for the 220 kV switchyard
- Upgrade Fire detection and suppression systems

Benefits and investment drivers:

- Reliability (primary project justification)
- Improved safety
- Improved visual amenity at the site
- Releasing space for future developments on site

Related documents:

- Planning Report Project XA14 West Melbourne Terminal Station Redevelopment
- Board paper: West Melbourne Terminal Station Project (15 May 2012)
- Business Case Application for Approval: XA14 WMTS Redevelopment Project

8.2.2 Springvale Terminal Station Redevelopment (XB61)

Summary:

Springvale Terminal Station (SVTS) is located in south-east Melbourne. It supplies the eastern Melbourne zone substations of Clarinda, East Burwood, Glen Waverley, Notting Hill, Noble Park, Oakleigh East, Riversdale, and three stations via 66 kV feeders.

Many of the primary and secondary assets at SVTS have advanced deterioration and are approaching end of life. The risks associated with plant failure are increasing and assets are becoming more difficult and expensive to maintain. This is, in part, because the manufacturers no longer support many of these assets and spare parts are now generally unavailable.

Economic studies support their replacement in the next period taking into account the probability and cost of failure risk. A staged redevelopment using 220 kV and 66 kV air insulated switchgear and 150 MVA transformers will be undertaken to address asset condition and circuit configuration risks at SVTS. This project is planned to commence in 2017/18 and be completed in 2021/22.

The table below provides the forecast expenditure for the review period.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	1,307	7,841	16,988	20,908	17,968	65,012

Table 14 – Expenditure on Springvale Terminal Station Redevelopment (XB61)

Scope of works:

- Replace three of the four 150 MVA 220/66 kV transformers
- Replace 220 kV switchgear and reconfigure the transformer and line connections
- Upgrade 220 kV busbars
- Replace 66 kV switchgear
- Upgrade 66 kV busbars
- Replace secondary systems

Benefits and investment drivers:

- Reliability (primary project justification)
- Safety
- Environmental
- Reduced operational and maintenance costs
- Reduced risk of plant collateral damage
- Reduced maintenance

Related documents:

- Planning Report Project XB61 Springvale Terminal Station Redevelopment
- AMS 10-67 Power Transformers and Oil Filled Reactors
- AMS 10-64 Instrument Transformers
- AMS 10-54 Circuit Breakers

8.2.3 Fisherman's Bend Terminal Station Refurbishment Stage 2 285A

Summary:

Fisherman's Bend Terminal Station (FBTS) is located approximately 3 km south-west of Melbourne's CBD and is the main source of supply for Docklands and Southbank, Port Melbourne, Fisherman's Bend, Albert Park, Middle Park and St Kilda West.

Established in late 1960s, FBTS has primary and secondary assets which have deteriorated and which are at an increasing risk of failure and have inefficient operation and higher maintenance costs. Economic studies support their replacement in the next period taking into account the probability and cost of failure risk. This project is the second phase of refurbishment at this site and is being undertaken earlier than originally planned due to further deterioration of the transformers. The scope involves replacing the B1 and B3 transformers, rebuilding the 220 kV switchyard into a more reliable breaker and a half configuration and replacing eight 66kV circuit breakers. The timing of the expenditure at Fisherman's Bend is provided in the following table.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	638	8,289	14,027	8,926	0	31,880

Table 15 – Expenditure on Fisherman's Bend Terminal Station Refurbishment

Scope of works:

- Replace the B1 and B3 transformers with new 150 MVA 220/66 kV transformers in situ.
- Replace critical 220 kV Circuit breakers and create breaker and a half bays to switch the incoming 220 kV lines
- Replace eight 66 kV feeder breakers
- Replace No4 220 kV capacitor bank CTs.

Benefits and investment drivers:

- Reliability (primary project justification)
- Safety
- Environmental
- Reduced maintenance

Related documents:

- Planning Report Project – XC17 Fisherman's Bend Terminal Station Refurbishment
- AMS 10-67 Power Transformers and Oil Filled Reactors
- AMS 10-54 Circuit Breakers
- AMS 10-24 Victorian Electricity Transmission Network – Asset Renewal Planning Guideline

8.2.4 Templestowe Terminal Station Transformer and Circuit Breakers Replacement (XC15)

Summary:

Templestowe Terminal Station (TSTS) is located approximately 25km north-east from Melbourne's CBD, (Melway map reference 34 E-2) and is the main source of supply for a major part of north-eastern metropolitan Melbourne. The TSTS supply area spans from Eltham in the north to Canterbury in the south and from Mitcham in the east to Kew in the West.

One of the three Victorian synchronous condensers (SCO) is located at TSTS to provide dynamic reactive support to the transmission system.

TSTS was established in the 1960's. The B2 transformer was installed in 1966 and the B3 unit in 1968. A third transformer was installed in the early eighties. The B2 and B3 transformers are both approaching end of life as is much of the 66kV switchgear which was installed about the same time as the transformers. Most of the 220 kV circuit breakers and current transformers at TSTS have been replaced in previous projects. The table below provides the forecast expenditure for the review period.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	0	0	581	7,551	12,778	20,910

Table 16 – Expenditure on Templestowe Terminal Station Replace B2 Transformer, Fifteen 66kV Circuit Breakers and install new protection and control systems

Scope of works:

- Replace B2 220/66 kV transformer
- 220 kV single switching of the existing B1 and B3 transformers
- Replace the station service transformers
- Install new 66 kV bus voltage transformers.
- Replace thirteen 66 kV circuit breakers and install new protection and control

Benefits and investment drivers:

- Reliability (primary project justification)
- Safety
- Environmental
- Reduced operational and maintenance costs
- Reduced risk of plant collateral damage
- Reduced maintenance

Related documents:

- Planning Report Project XC15 – Templestowe Terminal Station Replace B4 transformer and six 66 kV circuit breakers
- AMS 10-54 Circuit Breakers
- AMS 10-67 Power Transformers and Oil Filled Reactors
- AMS 10-24 Victorian Electricity Transmission Network – Asset Renewal Planning Guideline

8.2.5 Ringwood Terminal Station Transformer and Circuit Breakers Replacement (XC21)

Summary:

Ringwood Terminal Station (RWTS) is located approximately 25km east from Melbourne's CBD and supplies a major part of outer-eastern metropolitan Melbourne. The supply area spans from Lilydale and Woori Yallock in the north-east, to Croydon, Bayswater and Boronia in the east and more centrally, Box Hill, Nunawading, Mitcham and Ringwood.

RWTS was commissioned in 1963 and currently being partially redeveloped (Project X7F0) to replace the 220/22 kV transformers and outdoor 22 kV switchgear which present a high risk of failure. A second project (XB54) has recently replaced the next group of high risk assets – deteriorated bulk oil 220 kV circuit breakers. This occurred between 2014 and 2015.

Once these projects are completed, at the end of 2015, several important but deteriorated assets will still remain on the site. These include a 220/66 kV B4 transformer and 66 kV circuit breakers. This project will replace the B4 220/66 kV transformer and nine 66 kV circuit breakers and change the circuit configuration to reduce the probability of multiple transformer outages arising from a single asset failure. This project is scheduled for completion in 2018/19.

This project is being completed later than economic timing suggests smoothing expenditure and workloads across the planning period. The table below provides the forecast expenditure of the review period.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	6,076	3,867	0	0	0	9,943

Table 17 – Expenditure on Ringwood Terminal Station Replace B4 Transformer and Six 66kV Circuit Breakers

Scope of works:

- Replace B4 220/66 kV transformer
- Replace nine 66 kV circuit breakers
- Relocate No 2 B capacitor bank to new location
- Install new protection and upgrade AC/DC supplies, SCADA (Supervisory Control and Data Acquisition) and communication.

Benefits and investment drivers:

- Reliability (primary project justification)
- Safety
- Environmental
- Reduced operational and maintenance costs
- Reduced risk of plant collateral damage
- Reduced maintenance

Related documents:

- Planning Report Project XC21 – Ringwood Terminal Station Replace B4 transformer and six 66 kV circuit breakers
- AMS 10-54 Circuit Breakers
- AMS 10-67 Power Transformers and Oil Filled Reactors

8.2.6 Heywood Terminal Station Circuit Breaker Replacement (284A)

Summary:

Heywood Terminal Station (HYTS) is located in south western Victoria and is the main terminal station interconnecting the Victorian 500 kV transmission back bone with the South Australian transmission network via a double circuit 275 kV line. HYTS also supplies the Portland aluminium smelter via a double circuit 500 kV line

HYTS includes a 500 kV and a 275 kV switchyard, two remote 500 kV circuit breakers to connect the two 500 kV lines from Tarrone Terminal Station and Mortlake Power Station and connections for a double circuit 275 kV line to South East Substation in South Australia. HYTS also has two 370 MVA 500/275 kV transformers. A third 500/275 kV transformer is being installed as part of the AEMO initiated Victoria-South Australia interconnector upgrade project.

Some of the 500 kV circuit breakers at HYTS are in a poor condition with an increasing risk of failure. Condition assessments indicate that these assets are approaching the end of their technical lives. The supply risks associated with the failure of these key circuit breakers is increasing and these assets are becoming more difficult and expensive to maintain or refurbish due to the inflexible switching arrangements at HYTS. It is very difficult to obtain plant outages for maintenance or refurbishment.

This project proposes a selective replacement of critical circuit breakers together with some circuit breaker refurbishment. The table below provides the forecast expenditure of the review period.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	3,046	1,938	0	0	0	4,984

Table 18 – Expenditure on Heywood Terminal Station Circuit Breaker Replacement

Scope of works:

- Installing two new 500 kV circuit breakers at HYTS to allow the 500 kV line T-connections (Tarrone/APD and Mortlake/APD) to be double switched
- Replacing the APD No.1 line 500 kV remote circuit breaker in situ
- Retiring the APD No. 2 line 500 kV remote circuit breaker
- Refurbishing the two existing 500 kV circuit breakers that connects the 500 kV line T-connections (Tarrone/APD and Mortlake/APD) at HYTS
- Secondary Equipment replacement

Benefits and investment drivers:

- Reduction in health and safety risk due to plant explosive failures;
- Reduction in supply risk due to unplanned outages;
- Reduction in environmental risk due to insulating oil spillage;
- Reduction in collateral plant damage risk due to explosive plant failures;
- Reduction in operation and maintenance cost, including network losses.

Related documents:

- Planning Report Project 284A – Heywood Terminal Station Circuit Breaker Replacement
- AMS 10-54 Circuit Breakers
- AMS 10-64 Instrument Transformers

8.3 Communications Program

8.3.1 Network Technology

Summary:

AusNet Services' telecommunications network consists of a number of technologies that enable the communications and data interconnectivity of various systems, applications and devices. Over 3,500 circuits cater for various protection, SCADA, control and signalling, business/data gathering (Wide Area Network) and telephony systems. Many of these applications are mission critical to the operation of the transmission electricity network, such that any failure of the corresponding communications channel to effectively perform its function will inhibit the ability to effectively operate the electricity network within its operational constraints.

Information and Communications Technology (ICT) systems within AusNet Services' network typically experience rapid technological evolution, particularly when compared to other electricity network assets. This results in new assets becoming obsolete over a 5-15 year period. Obsolete equipment is normally uneconomic to maintain, either because it is incompatible with newer equipment or because it is no longer supported by manufacturers.

Additional communication investment is also being driven by evolving data transport needs. This includes the migration of some systems onto the Ethernet/IP (packet) system and a general growth in demand for bandwidth. As with the rest of the world, the demand for increased bandwidth is being driven by even more data intensive applications and an increasing number of connected devices.

The Network Technology program of work will replace a number of obsolete communications systems such as point to point radio links, asset data gathering packet-based network elements and the operational telephony network.

The following table provides an estimate of the network technology component of the communications capital budget from 2017 until 2022.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	7,770	8,280	3,010	5,390	5,420	29,870

Table 19 – Expenditure on Network Technology

Scope of works:

- Replace 66 SDH nodes at 33 sites
- Replace 302 PDH nodes at 67 sites.
- Install 80 new Ethernet switches at 29 sites.
- Install 60 new serial servers are 29 sites.
- Replace Operational Telephony Network (OTN)
    - Replace 36 Telephone exchanges at terminal Stations
    - Call logging and recording systems
    - CEOT telephone console systems.
- Migration of landlines to the National Broadband (NBN) leased services.

Benefits and Investment drivers:

- Safety
- Reliability
- Enabling new technology (which reduces operating costs)

Related documents:

- 2017-22 Program of Works – Communication Network Technologies
- AMS 10-56 Communications Systems

8.3.2 Bearers

Summary:

The communications network is installed, operated and maintained to enable AusNet Services meet its obligations as a Transmission Network Service Provider (TNSP).

AusNet Services, as a TNSP, must ensure that protection operation signals, remote control, power system data, and voice traffic of Extra High Voltage (EHV) terminal stations and generating stations function as stipulated in the rules and regulations set by NER and AEMO.

Other communications traffic carried on the network supports functions within AusNet Services that contribute to company meeting its code and agreement obligations.

AusNet Services still maintains some "legacy" bearer technologies (i.e. PLC, copper supervisory) that are struggling to meet both the technological and regulatory requirements of operating and maintaining the electricity transmission network. Increasing bandwidth and performance requirements are driving changes to bearers capable of delivering higher bandwidth digital services.

Where justified, optical fibre cable (e.g. OPGW) is now the preferred bearer for the AusNet Services communication systems to enable the establishment of modern optical communications systems and applications. The OPGW option is reinforced by the EHV ground wire replacement project which reduces the cost of replacing PLC with optical fibre. From a power system operational requirement, it has been identified that the existing PLC bearers do not respond to some specific fault instances. Therefore, PLC bearers should be replaced or where the cost is prohibitive, the old bearers should be replaced with newer (digital) models to reduce the risk of failure of the EHV network due to loss of communication signal and failure of control and protection equipment to operate.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	435	1,774	8,107	5,457	0	15,773

Table 20 – Expenditure on Bearers

Scope of works:

The work will include:

- Replacement of metallic PLC link with OPGW from Horsham Terminal Station to Ararat Terminal Station.
- Install new PLC link from Red Cliffs Terminal Station to Broken Hill Substation including line traps
- Install Radio link from Red Cliffs Terminal Station to Broken Hill Substation
- Replace All Dielectric Self Supporting (ADSS) from Hazelwood Terminal Station, Morwell Terminal Station and Yallourn Terminal Station to test hut 5.
- Replace 9 point to point radio systems
- Replace Power Line carrier (PLC) equipment between Mount Beauty Terminal Station and Dartmouth Power station and between Horsham Terminal Station and Red Cliffs Terminal Station.

Benefits and Investment drivers:

- Safety
- Reliability
- Compliance
- Enabling new technology (which reduces operating costs)

Related documents:

- 2017-22 Program of Works – Communication Network Bearers
- AMS 10-56 Communications Systems
- AMS 10-79 Transmission Line Conductors

8.3.3 Communications Infrastructure

Summary:

Supporting infrastructure and systems consist of power supplies, antenna equipment, towers, buildings, air conditioning systems, physical security, and operational support systems. This program of works concentrates on operational support systems, power supplies, air conditioners, and antenna equipment.

Communication supporting infrastructure assets are essential to supporting the communications system, but do not actively carry or transport communications traffic. These assets include:

- Antenna towers and associated attachments
- Radio site buildings and fencing
- 48VDC batteries and charging systems
- Standby generators
- Air conditioning systems
- Reticulation cabling

Dedicated communication sites, buildings and antenna structures are generally in good physical condition. However, some sites require improvement of the physical security given their remote nature and lack of modern key access and site monitoring.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	487	1,683	2,840	1,423	1,786	8,219

Table 21 – Expenditure on Communications Infrastructure

Scope of works:

- Replace DC battery systems at 40 sites.
- Install air conditioning systems at 50 sites.
- Replace wave guide connectors at 25 sites.
- Design and build two external diesel generator sets
- Design and build an out-of-band network for management of communication devices, upgrade network management systems and establish a test laboratory

Benefits and Investment drivers:

- Safety
- Reliability
- Enabling new technology (which reduces operating costs)

Related documents:

- 2017-22 Program of Works – Communication Network Supporting Infrastructure and Systems
- AMS 10-56 Communications Systems

8.3.4 Security

Summary:

AusNet Services' remote radio sites are typically located in remote locations, utilise hard keys for site/building access, and are accessed by personnel from a number of (3rd party) organisations. The sharing arrangement with third parties and lack of a standardised security implementation at the remote sites exposes the communication network to risks which could impact the operation of the Victorian electricity transmission network.

This program is aimed at improving and enhancing the physical and cyber security of the communication network assets. The proposed improvements will align the management of the communication assets with the AusNet Services Mission Zero principles.

Physical security and safety is aimed at addressing issues at remote radio sites. The scope of work is mainly to enhance the current physical security and safety of the sites.

For cyber security, programs are aimed at implementing Terminal Station Security Architecture and implementing Authorisation and Access Control systems.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	1,333	283	755	0	1,378	3,749

Table 22 – Expenditure on Communications Security

Scope of works:

- Install electronic gate system at 31 radio communication sites
- Implementing Terminal Station Security Architecture.
- Implementing Authentication and Access Controls for ICS systems.
- Improving earthing of radio infrastructure at 31 radio communication sites

Benefits and Investment drivers:

- Safety of personnel
- Security of communication systems
- Compliance
- Reliability

Related documents:

- 2017-22 Program of Works – Safety and Security of Communications Assets
- AMS 10-56 Communications Systems

8.4 Lines

8.4.1 Tower Strengthening

Summary:

AusNet Services has over 12,800 steel lattice towers supporting transmission lines. Early towers were not built to the current design standard and some of them are not able to withstand convective downdraft winds during storm events.

Towers on the Murray Switching Station to Dederang 330kV line have these structural constraints and are susceptible to failures induced by high intensity winds. AusNet Services can recover network functionality following a tower collapse using Emergency Restoration Structures (EMR). However, a tower collapse on the lines will significantly constrain the national electricity market until the EMR are installed and collapse may cause injury or death, ignite a bush fire or damage property.

This project will reinforce 48 towers on the lines by 2020 thus reducing the risk of failure. It will focus on towers with a high consequence of collapse due to their proximity to rail and road crossings.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	23	3,519	0	0	0	3,542

Table 23 – Expenditure on Tower Strengthening

Scope of works:

- Reinforce 48 towers carrying MSS-DDTS No1 and No2 lines

Benefits and investment drivers:

- Improved public safety
- Improved reliability for line and removed constraint on national electricity market (primary project justification)

Related documents:

- 2017-22 Program of Works – MSS-DDTS 1 and 2 - 330kV lines Tower Upgrade Program
- AMS 10-77 Transmission Line Structures
- Asset Management Strategy for the Victorian Electricity Transmission Network (AMS 10-01)

8.4.2 Conductor and Ground Wire Replacements

Summary:

The AusNet Services transmission system contains approximately 40,500 km of conductors in 17,800 spans, including spans within Terminal Stations.

Three different types of phase conductors are used including aluminium conductor steel reinforced (ACSR), all aluminium conductor (AAC) and all aluminium alloy conductor (AAAC).

No specific conductor replacement has been identified for this period. SAIP (Smart Aerial Imaging and Processing) is soon to be introduced as part of preventative maintenance strategies for the early identification of issues and defects. It is expected that some conductors in the more corrosive environments will meet end of life in the next 10 to 15 years and SAIP will help target those spans that need to be replaced.

There are also approximately 20,400 spans of groundwire on transmission lines and terminal stations in the AusNet Services network. The groundwires are strung above conductors and plant on lines and stations to protect the lines and plant from lightning strikes, thereby reducing outages and damage. The secondary purposes of groundwires are to provide a return path for fault currents and to reduce step and touch potentials at a structure in the event of a fault. In more recent times, groundwires include optical fibres in their core to provide an additional function of a high speed communications network between stations.

Steel conductors are often used for groundwires. However, ACSR is now the preferred option for new groundwires as its higher conductivity provides a better fault current return path and better reduction in step and touch potentials at tower sites. However, steel groundwires still make up approximately 44% of the population and are also the oldest groundwires.

The groundwire replacement program plan for the 2017-22 period is to replace approximately 226 km of groundwire with 154 km of standard groundwire and 72 km of OPGW. The program will target replacing sections of 11 transmission lines that have been identified as being in poor condition and close to end of life due to corrosion. Estimated expenditure is provided in the following table.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	3,802	3,802	3,802	3,802	3,802	19,010

Table 24 – Expenditure on Conductor and Ground wire replacements

Scope of works:

Replace the following sections of groundwire

- 8km KTS-BLTS T36-48 (1 x 4 km ASCR, 1 x 4 km OPGW)
- 4km KTS-GTS 1,3 157-166
- 10km TTS-KTS 2 1-38
- 6km TTS-KTS 1 38-57
- 15km ROTS-MTS 341-389
- 15km ROTS-RTS 1 341-389
- 15km ROTS-RTS 4 341-389 (OPGW)
- 5km CBTS-FTS
- 26km DDTS-SMTS2 515-550 (2x13km)
- 19km HWPS-ROTS 279-339
- 19km YPS-ROTS 7&8 279-339
- 8km SVTS-HTS 2
- 53km YPS-ROTS 5,6 (120-264 and 317-ROTS) (OPGW)

Benefits and investment drivers:

- Public health and safety by reducing step and touch potential of towers.
- Preventing bushfire ignition
- Mitigate incentive scheme penalties for line outages
- Avoid emergency repair costs
- Reduce the risk of loss of supply to many customers
- Prevent damage to third party assets

Related documents:

- AMS 10–79 Transmission Line Conductors
- 2017-22 Program of Works - Transmission Line Conductor and Ground-wire Replacement Program

8.4.3 Tower and Station Rack – Fall Arrest Installation

Summary:

AusNet Services has over 12,800 EHV towers which are climbed at least once every three years for inspection purposes. To meet Occupational Health and Safety Regulations 2007, No 54 part 3, permanent fall arrest systems will be installed on towers to prevent the risk of injury to personnel. Since 2010, after assessment of the most suitable system, the Latchways cable fall arrest system has been adopted and AusNet Services has been progressively installing this system. It now covers 53% of the EHV tower fleet.

In the period 2017-2022, the program will continue and AusNet services will install the arrest systems on a further 25% of the tower fleet by 2022. The FAS will be installed on towers with flat delta configurations (on 330kV and 500kV fleet), which requires a horizontal system for line workers in addition to the vertical system.

In addition to the towers, AusNet Services has 650 rack and ancillary structures located within terminal stations that are also climbed at least once every three years as part of their condition assessment inspections. Fall arrest systems are also being installed on these structures. This installation is part of a separate program which will install fall arrest systems on 38% of the rack and ancillary structure within terminal stations and complement the 62% of structures that already have been completed.

The implementation of these two programs will significantly reduce AusNet Services' risk profile of accidents related to a fall while accessing a tower, and increase productivity by providing faster climbing rate to line workers and maintenance crews.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	4,314	4,314	4,314	4,314	4,314	21,570

Table 25 – Expenditure on Structure Fall Arrest Installation

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	8	341	529	0	0	878

Table 26 – Expenditure on Station Rack Fall Arrest Installation

Scope of works:

- Install cable based fall arrest systems across 25.2% of towers
- Install cable based fall arrest systems on 38% rack structures and other ancillaries at terminal stations.

Benefits and investment drivers:

- Compliance (primary project justification)
- Safety
- Maintenance costs

Related documents:

- 2017-22 Program of Works – Rack Structure Fall Arrest Systems
- 2017-22 Program of Works – Structures (Towers): Fall Arrest Installation Program
- AMS 10-77 Transmission Line Structures

8.4.4 Insulator Replacement

Summary:

There are 89,500 transmission line insulator strings in service on the transmission network as at June 2015. Failure of these assets can lead to circuit outages and falling overhead conductors, which are a high risk to public safety and to a lesser risk to network reliability and security.

Since 2015, 6,114 insulator strings have been replaced based on condition data gathered during tower climbing inspections. Typically, this has involved replacing insulators with corroded pins, which are at risk of mechanical failure. Since this program began, there have been no major insulator failures. There remains however small volumes of insulators in service which are in poor condition and, due to their proximity to rail and road crossings, pose a high risk public safety if they fail. The current replacement program will continue through 2022 albeit at a reduced level. Replacement of 2.3% of the existing insulator fleet by 2022 is planned which will remove risks associated with major failure of transmission line insulators for this period.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	1,134	1,070	1,070	1,070	887	5,231

Table 27 – Expenditure on Insulator Replacement

Scope of works:

- Planned replacement of 2.3% of the insulator fleet which present public safety risks

Benefits and investment drivers:

- Improved public safety (primary project justification)
- Improved employee safety
- Improved Reliability
- Compliance

Related documents:

- AMS 10-75: Transmission Line Insulators
- Electricity safety legislation.
- 2017-22 Program of Works – Transmission Line Insulator Replacement Program

8.5 Secondary, Protection and DC Program

AusNet Services will implement a whole of station approach to relay replacement in the next period whereby all the secondary equipment at the same location will be replaced as part of the same program. This is different to the current period where relays of a certain type were targeted for replacement in a number of terminal stations and their replacement was run as a single project.

The advantages of this approach are:-

- It allows for a more efficient and effective installation program. In particular, it simplifies the planning of the numerous plant outages that are required as part of the complex relay replacement programs.
- The development of multifunction microprocessor equipment allows one device to provide both control and protection functions making it cost effective to install devices that replace a number of legacy relays.
- The inputs and outputs from the RTU are no longer hard wired to the relay but instead use a communications bus. This makes it cost effective to include RTU replacements with relay replacement projects.

8.5.1 Control Systems

Summary:

Control systems include a range of equipment that provides either automatic or remote control of primary assets. These types of system are essential for the effective and efficient operation of the network and include transformer voltage regulation and cooling control, VAR control, load shedding and runback schemes. Runback schemes monitor load transfer through interstate connectors ensuring network stability is maintained.

Control technology changes rapidly, especially compared to the technology for primary electrical assets. Consequently, new control equipment typically becomes obsolete over a 10 year period. When this happens it can become uneconomic to retain the equipment, either because it is incompatible with newer equipment or because it is no longer supported by manufacturers and cannot be maintained. Additionally, some obsolete equipment does not comply with relevant industry rules for control and protection equipment. Some plant control schemes are old and their failure may result in outages which may be indefinite and which will incur penalties through the incentive schemes.

Adding to the issues with older schemes is the lack of internal and external expertise to repair and modify them.

8.5.2 Protection Systems

Summary:

Protection systems are an essential part of the electricity transmission network. They detect faults and operate circuit breakers to rapidly disconnect faulted circuits from the healthy network, limiting the exposure of workers and the general public to unsafe voltages and currents, maintaining network operating voltage within sustainable limits and limiting damage to electrical plant and equipment. Failure of protection schemes to clear faults can cause generator and network instability, cascade tripping and widespread blackouts.

Protection system technology is changing rapidly, especially compared to the technology for primary electrical assets. Protection relays have evolved quite rapidly from electromagnetic technology to microprocessor technology within a few decades. Even the new microprocessor based digital devices are evolving, integrating multiple functions. Microprocessor based protection assets typically become obsolete within a 15 year period.

Obsolete protection equipment is often uneconomic to integrate into modern systems as it limits the necessary functionality of newer equipment. Additionally, older equipment it is no longer supported by manufacturers and cannot be economically maintained. Some obsolete equipment cannot comply with relevant industry rules for protection system performance and functionality.

Over the forthcoming regulatory period AusNet Services' protection systems program is targeted at replacing non-compliant and non-supported protection assets which are not included in the scopes of work of major asset replacement projects.

8.5.3 Monitoring and Metering

Summary:

Secondary systems include devices to measure network operating parameters and monitor the status of network assets. This data is essential for the effective operation of the network and improves the strategic planning and operational management of primary assets. Examples include, revenue metering, power quality monitoring, transformer loading and temperature monitoring, circuit breaker operation, insulating oil degradation, and prevailing weather.

The SCADA system gathers remote station data such as instrumentation (volts, amps, frequency, watts, VARs, transformer temperature, conductor strain, environmental measurements) circuit breaker and plant status, station alarms, interprets it and displays it to operations personnel to take appropriate action to control the network.

The revenue meters monitor wholesale energy flows, calculate losses and facilitate invoicing amongst National Electricity Market (NEM) participants.

Similar to other secondary equipment, monitoring and measuring technology is constantly developing and new secondary assets typically become obsolete over a 15 year period. Obsolete monitoring equipment is normally uneconomic to maintain, either because it is incompatible with newer equipment or because it is no longer supported by manufacturers. Over the forthcoming regulatory period non-compliant and non-supported assets will be replaced. This program focusses on those monitoring and metering assets which are not included in the scope of works for major asset replacement projects.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	19,555	15,588	11,655	11,280	11,317	69,395

Table 28 – Expenditure on Protection Control and Monitoring and Metering

Benefits and investment drivers:

- Protection of primary assets from overload or fault currents
- Effective and efficient operation of the Transmission Network
- Elimination of risk of extended outage
- Safety for both public and AusNet Services' personnel
- Compliance with legislation
- Operating and capital efficiency
- Network reliability and security
- Lower life cycle costs

Related documents:

- AMS 10-68: Secondary Systems (Protection, Control & Automation Assets)
- 2017-22 Program of Works – Secondary Systems

Scope of Works:

The scope of works for protection control and monitoring programs is as follows:

- Upgrade the CB management relays at Sydenham Terminal Station (SYTS), Templestowe Terminal Station (TSTS), Rowville Terminal Station (ROTS), Keilor Terminal Station (KTS) and South Morang Terminal Station (SMTS)
- Replace the remote terminal unit (RTU) and control systems at East Rowville Terminal Station (ERTS), Ballarat Terminal Station (BATS), Bendigo Terminal Stations (BETS) and Brooklyn Terminal Station (BLTS).
- Replace Capacitor Bank and Reactor M40 Izumi PLC automatic voltage controls (AVC) Controls at various Terminal Stations.
- Replace PLC based network Control Schemes (DBUSS, VFRB, BARBS) at various Terminal Stations.
- Replace Control Systems at Kerang Terminal Station (KGTS)
- Replace Load Shedding Schemes at Brunswick Terminal Station and Cranbourne Terminal Station (CBTS).
- Replacement of Load Shedding Schemes at 24 Stations
- Replacement of Weather Stations at 22 Terminal Stations
- Complete the Static VAR Compensator protection upgrade at Kerang Terminal Station (KGTS)
- Complete the Static VAR Compensator protection upgrade and Thyristor control replacements at Rowville Terminal Station (ROTS)
- Replace critical protection relays at various Terminal Stations
- Complete the migration of the Protection Setting Relay data base to a SAP compatible platform
- Complete the upgrade of protection inter-tripping (DC) circuits at Hazelwood Power Station (HWPS)
- Replace protection, control and RTU systems at Rowville Terminal Station (RWTS)
- Replace protection, control and RTU systems at Red Cliffs Terminal Station (RCTS)
- Replace protection and RTU systems at Dederang Terminal Station (DDTS)
- Replace protection systems at Horsham Terminal Station (HOTS)
- Replace protection and RTU systems at Terang Terminal Station (TGTS)
- Replace WPD 66kV feeder protection at Geelong Terminal Station (GTS)
- Replace protection and control systems at Moorabool Terminal Station (MLTS)
- Replace protection and control systems at Shepparton Terminal Station (SHTS)

- Replace protection and RTU systems at Yallourn Power Station (YPS)
- Replace the Static VAR Compensator control and protection at Horsham Terminal Station (HOTS).
- Replace protection and control systems at Keilor Terminal Station (KTS)
- Replace energy metering at various substations.

8.5.4 DC Supply Systems

Summary:

The Victorian electricity transmission network includes more than 240 individual Direct Current (DC) power supply system's comprising batteries, battery chargers, DC power distribution switch boards, isolation, wiring and monitoring and alarm equipment. The DC power systems are located in terminal stations to provide critical DC power for the operation of electrical protection, control, metering and SCADA systems associated with the electricity transmission network. Complete failure of DC supplies at a terminal station renders energy flows and station equipment uncontrollable and disables electrical protection system placing consumer, public and worker safety at risk.

The Australian Energy Market Operator's (AEMO's) Protection and Control Requirements specify duplicated and physically segregated "X" & "Y" DC batteries and chargers are provided with sufficient capacity to run identified station DC services for up to 10 hours. Batteries are essential to the station protection and control systems, communications, and remote control and energy monitoring. They also present risks in respect of acid spills, potential for explosion and injury to workers during manual handling.

Replacement of DC system assets is typically driven by duty related degradation, which occurs faster than for many primary assets. Batteries, in particular, degrade quickly and typically last only 15 years. Currently, the oldest batteries have been in service for 20 years. This project will focus on replacing the oldest batteries and related systems.

- Performance risks and functionality limitations of deteriorating batteries and chargers beyond their economic service life,
- Occupational health and safety risks associated with maintaining batteries and battery rooms in compliance with current Australian Standards, and
- Establishment of a condition monitoring program for economic management of DC systems.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	1,250	2,100	3,350	3,000	3,800	13,500

Table 29 – Expenditure on DC Supply

Scope of works:

- Replacement of X and Y 250V DC batteries at Ballarat Terminal Station. Establish a new battery room.
- Replacement of X and Y 250V DC batteries and battery chargers, A and B 48V DC batteries and battery chargers and establishment of a new battery room at Eildon Power Station.
- Replacement of X and Y 250V DC batteries and battery chargers, A and B 48V DC batteries and battery chargers and establishment of a new battery room at Fosterville Terminal Station.
- Replacement of A and B 48V DC batteries and battery Chargers and 50V DC control battery and battery charger at Jeeralang Terminal Station.
- Replacement of X and Y 250V DC batteries and battery chargers, A and B 48V DC batteries and battery chargers and establishment of a new battery room at Mount Beauty Terminal Station.
- Replacement of 48V DC A and B batteries and battery chargers at Red Cliffs Terminal Station.
- Replacement of 48V DC A and B batteries at Springvale Terminal Station.

Benefits and investment drivers:

- Reliability of DC systems
- Protection and control of expensive primary assets

Related documents:

- 2017-22 Program of Works – Secondary Systems
- AMS 10-52 DC Power Supplies

8.6 Stations

8.6.1 Upgrade / Replacement of Fire Protection Systems

Summary:

Fire protection systems at terminal stations include detection and suppression capability to protect assets from fire damage, and maintain network security and reliability. These systems are designed to extinguish fires which may ignite around station assets such as transformer or in buildings. Existing protection systems mostly extinguish fires using automatic water deluge or sprinkler systems. Fire systems also include hydrants, fire detectors and signage.

A fire in a terminal station control building or in a relay building could result in network outages and loss of supply to customers. Uncontrolled fires within terminal station or communication buildings pose risks to the health and safety of employees and contractors. A major terminal station fire also poses a bushfire ignition risk under adverse weather conditions and therefore a risk to public safety.

Existing fire protection systems at some sites are deemed inadequate for a variety of reason including deterioration, corrosion and some obsolete systems are non-compliant with current Australian Standards. This program will replace and rebuild systems with condition grades of C4/C5 as well as address those systems which are non-compliant with Australian standards. Expenditure forecast is as follows:

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	1,755	1,755	1,755	1,755	1,755	8,775

Table 30 – Expenditure on Upgrade/ Replacement of Fire Protection Systems

Scope of works:

- Upgrade / replacement of fire hydrant systems at 11 terminal stations sites
- Upgrade / replacement of fire detectors and fire indicators panels (FIP) at 20 terminal stations
- Upgrade / replacement of deluge systems for 7 transformers installed at Keilor, Moorabool, Rowville and South Morang terminal stations
- Installation of fire walls at South Morang Terminal station (SMTS) required for spare transformers.
- Minor upgrade to fire hydrants systems at five terminal stations
- Upgrade or installation of signage at 25 terminal station sites.

Benefits and investment drivers:

- Network security and reliability
- Asset protection and damage mitigation
- Worker and public safety

Related documents:

- AMS 10-61 Fire detection and Suppression
- 2017-22 Program of Works – Fire Protection Systems

8.6.2 Infrastructure Security Systems Upgrade

Summary:

Infrastructure security systems protect network assets and network functionality from unauthorised entry to terminal station switch yards and control buildings. Unauthorised entry could result in significant damage to assets (intentional or unintentional) and outages which impact network security and the reliability of consumer supplies or death or severe injury to the unauthorised person.

The threat of terrorism has led the Commonwealth and State governments to impose legal responsibility on the owners and operators of critical infrastructure, such as electricity transmission installations to take all necessary preventative security measures to ensure the continuity of supply. The Victorian Terrorism (Community Protection) Act 2003 requires electricity and gas providers to develop and monitor risk management plans – including all appropriate preventative security and emergency restoration measures.

There are also obligations under the Electricity Safety Act to minimise the hazards and risks to persons and property and to prevent bushfires.

This project will upgrade security at selected sites to ensure compliance with this legislation and reduce the risks of unauthorised access to key assets in the Victorian electricity transmission network.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	2,500	2,500	2,500	2,500	2,500	12,500

Table 31 – Expenditure on Infrastructure Security Systems Upgrade

Scope of works:

- Install CCTV surveillance cameras at 15 sites
- Upgrade security fencing and access controlled vehicle gates at eight sites
- Install remotely operated switchyard lights at 15 sites
- Upgrade access control at ten sites
- Replacement of security fencing at ten sites.

Benefits and investment drivers:

- Compliance with legislative requirements with legislation
- Network Security and security of supply
- Asset damage mitigation

Related documents:

- AusNet Services Document AMS 10-63 – Infrastructure Security
- 2017-22 Program of Works - Security Systems Infrastructure Replacement
- Guideline for the Prevention of Unauthorised Access to Electricity Infrastructure, 2005 ENA.

8.6.3 CB Replacement Program

Summary:

The failure of circuit breakers (CB's) will cause network outages and are very likely to cause interruption to supplies. Network reliability will be affected until the emergency replacement of the failed CB's occurs.

Where the CB's are bulk oil type their failure can cause explosions and fires. The large volume of oil within the CB tank may spill oil and spread oil fires. Further, explosive failure of porcelain bushings on these CBs can result in projectiles. All of these issues will present a safety risk to people working in the switch yard. Spillage of oil also poses environmental hazards as bulk oil CBs are not positioned within a bunded area.

This program of work seeks to reduce the risk of failure of CBs near the end of life and in poor and very poor condition that aren't listed for replacement as part of an existing project or a proposed station rebuild and where refurbishment is not considered worthwhile.

Seventy-two circuit breakers have been identified for replacement at voltages form 22 kV to 500 kV. The proposed spending profile is provided in the following table.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	5,922	5,922	5,922	5,922	5,922	29,612

Table 32 – Expenditure on CB Replacement Program

Scope of works:

- Replace 7 off 500 SF_6 live tank breakers
- Replace 8 off 220 kV minimum oil breakers
- Replace 8 off 220 kV SF_6 live tank breakers
- Replace 11 off 66 kV bulk oil breakers minimum oil breakers
- Replace 21 off 66 kV SF_6 minimum oil breakers
- Replace 14 off 66 kV SF_6 live tank breakers
- Replace 3 off 22 kV SF_6 minimum oil breakers

Benefits and investment drivers:

- Network reliability, quality and security of supply
- Worker and public safety
- Avoid financial impacts of failures
- Comply with Regulatory Requirements

Related documents:

- AMS 10-54 Circuit Breakers
- 2017-22 Program of Works – Circuit Breaker Replacement

8.6.4 Instrument transformers including Current Transformers Replacements

Summary:

Instrument transformers include Current Transformers (CTs), Voltage Transformers (VTs) and Capacitive Voltage Transformers (CVTs). The primary insulating systems of oil filled porcelain-clad HV instrument transformers progressively deteriorates with duty and service age. Eventually deterioration accelerates leading to an explosive failure. The consequences of such a failure are well known – explosive failure. It can result in injury to nearby workers, damage to nearby equipment and unplanned network outages.

The condition of CTs and VTs is assessed using Dissolved Gas Analysis. This analysis combined with known asset defects and degradation patterns has identified 70 poor condition instrument transformers for replacement before March 2022. These replacements are in addition to the instrument transformers that will be replaced during major terminal station rebuilds. The program will be an extension of the existing project, for replacement of instrument transformers which is underway in the current regulatory period.

The works proposed include the removal of the existing plant and the installation of new plant on new foundations.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	1,480	1,480	1,480	1,480	1,480	7,400

Table 33 – Expenditure on Instrument Transformer Replacements

Scope of works:

- Replace twenty-eight 500 kV current transformers
- Replace twelve 220 kV current transformers
- Replace two 66 kV current transformers
- Replace one 500 kV capacitive voltage transformers
- Replace four 220 kV capacitive voltage transformers
- Replace one 66 kV capacitive voltage transformers
- Replace fourteen 66 kV magnetic voltage transformers
- Replace eight 22 kV capacitive voltage transformers

Benefits and investment drivers:

- Network reliability, quality and security of supply
- Safety and Environment
- Financial Impacts from incentive schemes, emergency replacements and market impacts
- Compliance with regulatory requirements.

Related documents:

- 2017-22 Program of Works – Instrumentation Transformer Replacement
- AMS 10-64 Instrument Transformers

8.6.5 Civil Infrastructure/ Station Facilities Assets Replacement

Summary:

Civil Infrastructure and station facilities house and support the safe operation and proper functioning of electrical equipment that forms the electricity transmission network. Infrastructure and facilities are needed, and often legally required, to maintain a safe work environment for employees and the public. Civil infrastructure houses high cost assets that would otherwise be damaged by exposure to dust or the weather and facilitates necessary maintenance which ensures low life cycle costs and economic service provision.

The scope for civil infrastructure and station facilities (CISF) assets replacement program covers upgrade /replacement works, at various terminal stations sites across the entire state, related with mainly following assets:

- All types of buildings including metallic, brick, cement clad or any other type of building or housings with / without asbestos.
- Switchyard surfaces, access roads, drainage systems, cable trenches, vegetation etc.
- Support structures such as steel structures, lighting poles, hand rails, retainer walls, and earth embankments/ flood levees, etc.
- Station service transformers and LV supply metallic cabinets in switchyards.
- Air conditioning and ventilation systems.
- Oil water separators and triple interceptor pits (environmental control equipment).

Economic and compliance analysis has identified civil assets which need to be replaced or upgraded over the forthcoming regulatory period to ensure safe reliable functioning of key electrical assets.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	1,770	1,770	1,770	1,770	1,770	8,850

Table 34 – Expenditure on Civil Infrastructure/ Station Facilities Assets Replacement

Scope of works:

- Replace asbestos tiles / cement sheets / claddings at 15 terminal stations
- Replace roofing of control buildings at 5 terminal stations
- Replace access roads / switchyard surfaces at 3 terminal stations
- Replace metallic cabinets and switchboards in 4 switchyards
- Replace retaining walls, handrails and support structures including lighting poles and flood protection levees at 3 terminal station
- Station Service Supply Upgrades at 3 terminal stations
- Provision for replacement of AC units and other minor replacement at 12 terminal stations

Benefits and investment drivers:

- Improve Occupational Health and Safety
- Comply with NER, Electrical, OH&S and Environmental legislation
- Extended asset life

Related documents:

- AMS 10 – 55 – Civil infrastructure
- 2017-22 Program of Works – Civil Infrastructure Replacement

8.6.6 Disconnectors and Earth Switches

Summary:

Disconnectors and Earth Switches are vital components for electrical isolation and earthing of key equipment in the electricity network. Together they provide safe access to equipment for inspection or maintenance and network operations. Major defects in disconnectors and earth switches cause impairment of their intended functions. Their correct operation is essential so that operating and maintenance staff can work safely on plant and switchgear with electrical isolation at earth potential. Failures of some types of older switches are becoming common and many switches have been tagged as inoperable due to unreliability and health and safety concerns. Major failures in critical switches cause inefficient network operations by causing cancellations or delays in carrying out planned maintenance work.

This program is to replace / refurbish 127 off deteriorated Disconnectors and Earth Switches at various Terminal Stations in Victorian electricity transmission network.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	848	2,440	2,440	2,440	2,440	10,608

Table 35 – Expenditure on Disconnectors & Earth Switches Assets Replacement

Scope of works:

Replace or refurbish the following deteriorated plant items:

- Ten 500kV Disconnectors
- Seven 330kV Disconnectors and Earth Switches
- Thirteen 220kV Disconnectors
- Forty nine 66kV fused isolators and underslung isolators
- Forty eight 11kV and 22kV fused isolators

Benefits and investment drivers:

- Improve Occupational Health and Safety
- Compliance regulatory obligations
- Extended asset life

Related documents:

- AMS 10-59 – Disconnectors and Earth Switches
- 2017-22 Program of Works – Disconnector and Earth Switch Replacement

8.6.7 Reactive Plant

Summary:

Reactive plant consists of capacitor banks, Static VAR compensators and Air Core Reactors. They are used to regulate the voltage of the transmission network under steady state and dynamic conditions. Their use reduces system losses and improves the power ratings of the many elements of the system.

The failure of reactive plant results in a reduction in or complete loss of ability to provide dynamic voltage support to the transmission network. This gives rise to increased system losses and restricted ratings on transmission lines and transformers as well as an overall reduction in effective station loading capability.

This program of work is to replace reactive plant which is in very poor and poor condition (assessed as C5 and C4) that aren't listed for replacement on existing projects or proposed station rebuilds.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	164	164	164	164	164	820

Table 36 – Expenditure on Reactive Plant Assets Replacement

Scope of works:

- Replace 12 off 10.5 kV thyristor switched reactor/capacitor wall bushings on the ROTS No2 SVC.
- Replace 3 off air core reactors on the ROTS No2 SVC.
- Replace 2 off GE neutral reactors
- Replace 1 off AEI type neutral reactors

Benefits and investment drivers:

- Occupational Health and Safety
- Network Reliability, quality and security of supply.
- Compliance
- Extended asset life

Related documents:

- 2017-22 Program of Works - Reactive Plant Replacement
- AMS 10-53 Capacitor Banks
- AMS 10-71 Static Var Compensators
- AMS 10-67 Power Transformers and Oil Filled Reactors

8.6.8 On-line Monitoring

Summary:

On-line-monitoring (OLM) enables frequent assessment of asset condition to detect trends in deterioration and reduce the need for inspection. The primary benefit of on-line monitoring is to develop an accurate understanding of asset condition which leads to the extension of asset lives. On-line monitors also reduce the need for outages thereby reducing the need for maintenance outages on ageing assets.

The program will install on-line monitors on the bushings of six of the main interconnecting transformers and SF6 live tank and dead tank circuit breakers that will have reached 15 years of service.

The intention of CB monitoring is to understand the condition of the CBs before their notional 20 year half-life refurbishment. Knowing the condition and the performance trends of the circuit breaker will also allow the half-life refurbishment time to be optimised. For power transformers, the monitoring will improve the planning and scheduling of outages and/or replacements for key transformers that can constrain the market when they are not available.

$'000 (Real 2015)	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
CBs	70	100	0	0	0	170
Transformer bushings	100	100	100	100	100	500
Total program	170	200	100	100	100	670

Table 37 – Expenditure on Replacement and Installation of On-line Monitoring

Scope of works:

- Install locally accessed OLMs on the bushings of six of the main interconnector transformers at three terminal stations
- Install OLMs on 10 CBs at two stations (ATS and TSTS)

Benefits and investment drivers:

- Improve Occupational Health and Safety by preventing failure of transformer bushings and circuit breakers.
- Compliance with regulatory requirements for quality, reliability and security of supply
- Extended asset life

Related documents:

- AMS 10-67 Power Transformers and Oil Filled Reactors
- 2017-22 Program of Works – Transformer Bushing Online Monitoring
- AMS 10-54 CB Asset Management Strategy
- 2017-22 Program of Works - Circuit Breaker Online Monitoring

8.6.9 Transformer – Improved safe maintenance access

Summary:

Periodic transformer maintenance requires workers to access gas relays and other equipment on the top of large power transformers. This generally involves working at significant heights and presents an ongoing fall risk. Current safety arrangements are insufficient to meet occupational health and safety standards for working at heights.

This project will retrofit handrails and ladder access points to fifty power transformers on the transmission network.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	500	500	500	500	500	2,500

Table 38 – Expenditure on Transformer - Improved safe maintenance access

Scope of works:

Retrofit to 50 transformers

- galvanised fence/handrail system with kick rail for each transformer tank lid
- two ladder access points to the lid
- a working platform and ladder access point to the Buchholz relay
- harness turnbuckle attachments to each bushing turret.

Benefits and investment drivers:

- Minimise OH&S risk (working at heights) to employees and contractors.
- Compliance with electrical safety and OH & S legislation

Related documents:

- 2017-22 Program of Works - Transformer Improved Safe Maintenance Access
- AMS 10-67 Power Transformers and Oil Filled Reactors

8.6.10 Transformer Bushing Replacement Program

Summary:

Bushings are a relatively small proportion of the cost of a transformer, but are a very important component, providing the connection between the transformer and external circuits. The failure of bushing insulation has a high probability of causing an explosion and oil fire. Many of such failures have resulted in the complete destruction of the transformer and damage to adjacent equipment. AusNet Services' network has experienced 220 kV bushing failures and transformer fires in 1965 and 1987. In last decade, four interstate bushing failures (two in Queensland and another two in New South Wales) have involved explosions, fire and complete loss of the entire transformer.

AusNet Services' oldest high voltage transformer bushings were installed in the 1960s and 1970s. Bushings from this period are of two basic designs; oil impregnated paper (OIP) and synthetic resin bonded paper (SRBP).

Two types of bushing are now showing signs of advanced age deterioration that would lead to an insulation failure and possibly an explosive transformer failure. They are proposed for replacement in the 2017-2022 regulatory period.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	680	680	680	680	680	3,400

Table 39 – Expenditure on Transformer – Bushing Replacement Program

Scope of works:

This program is to replace the following transformer bushings at four terminal stations:

- 1 off Toshiba OIP8 220 kV HV Bushing
- 9 off English Electric 500 kV OIP HV Bushings
- 3 off English Electric 66 kV MV Bushings
- 6 off English Electric 220 kV HV Bushings
- 3 off Micanite OIP 220 kV HV bushings

Benefits and investment drivers:

- Reliability (primary project justification) by avoiding unplanned outages and plant failures
- Reduced risk of collateral damage to other equipment which may occur during an explosive failure.
- Worker Safety due to the likelihood of projectiles, oil spills and fires.

[8] Oil Impregnated Paper.

Related documents:

- 2017-22 Program of Works – Transformer Bushings Replacement
- AMS 10-67 Power Transformers and Oil Filled reactors

8.6.11 Transformer – Life Extension

Summary:

A variety of asset management activities are used to extend the life of a transformer. Typically these activities are applied to transformers whose insulation and windings are in good condition and will last for a number of years so it is worthwhile to expend a moderate amount of money to extend their life.

These activities include repair of oil leaks, corrosion mitigation of the tanks, improving oil quality, insulation dry out and winding re-clamping, replacement of equipment, sensors and fittings and installation of on-line dissolved gas analysers.

The program of work is to perform one or more of these activities on 28 transformers in order to extend their life and to defer their replacement.

	FY17/18	FY18/19	FY19/20	FY20/21	FY21/22	Total
$'000 (Real 2015)	1,256	1,256	1,256	1,256	1,256	6,280

Table 40 – Expenditure on Transformer – Life Extension

Scope of works:

- Oil leak Repairs (17 transformers)
- Corrosion mitigation (8 transformers)
- Oil quality improvement (2 transformers)
- On site insulation dry-out and winding re-clamping (1 transformer)
- Replacement of defective and inaccurate fittings (5 transformers)
- Fitting of on-line dissolved gas analysers (4 transformers).

Benefits and investment drivers:

- Extend life of transformer
- Avoid transformer failure and financial impacts associated with unplanned outage
- Compliance with regulatory requirements for performance, reliability and security of supply.
- Avoid safety and environmental consequences associated with oils spills and transformer failure.

Related documents:

- AMS 10-67 Power Transformers and Oil Filled Reactors
- 2017-22 Program of Works – Transformer Life Extension

9 Deliverability

AusNet Services has undertaken a review of the deliverability of the forecast capital works. Deliverability refers to the ability of the business to deliver the proposed program of work and is dependent on availability of sufficient materials and resources (labour and equipment).

The proposed annual program of Capital and Operational works is smaller than the program in the 2014 to 2017 regulatory period but it encompasses similar activities. By contrast, the program for 2014 to 2017 period was a significant step increase from the previous period, an increase that AusNet Services was able to deliver. This demonstrates that the operating model used to deliver the program is robust and effective and can respond to change in volumes. Because the current period features a reduction in the program, the proposed program is not expected to present particular delivery challenges.

The following sections describe how AusNet Services is structured and organised to deliver the works program, initiatives undertaken in the current regulatory period to improve delivery, and how the approach results in efficient delivery.

9.1 Structure

A simplified version of AusNet Services' structure showing responsibilities for key components of the Capital and Operating program is shown in Figure 8. The Asset Management division is the group responsible for developing the overall program of Capital and Operating works. The Service Delivery division is responsible for delivering the program. Service Delivery is most affected by the size of the works program as the physical resources to deliver the program are retained or engaged by this division.

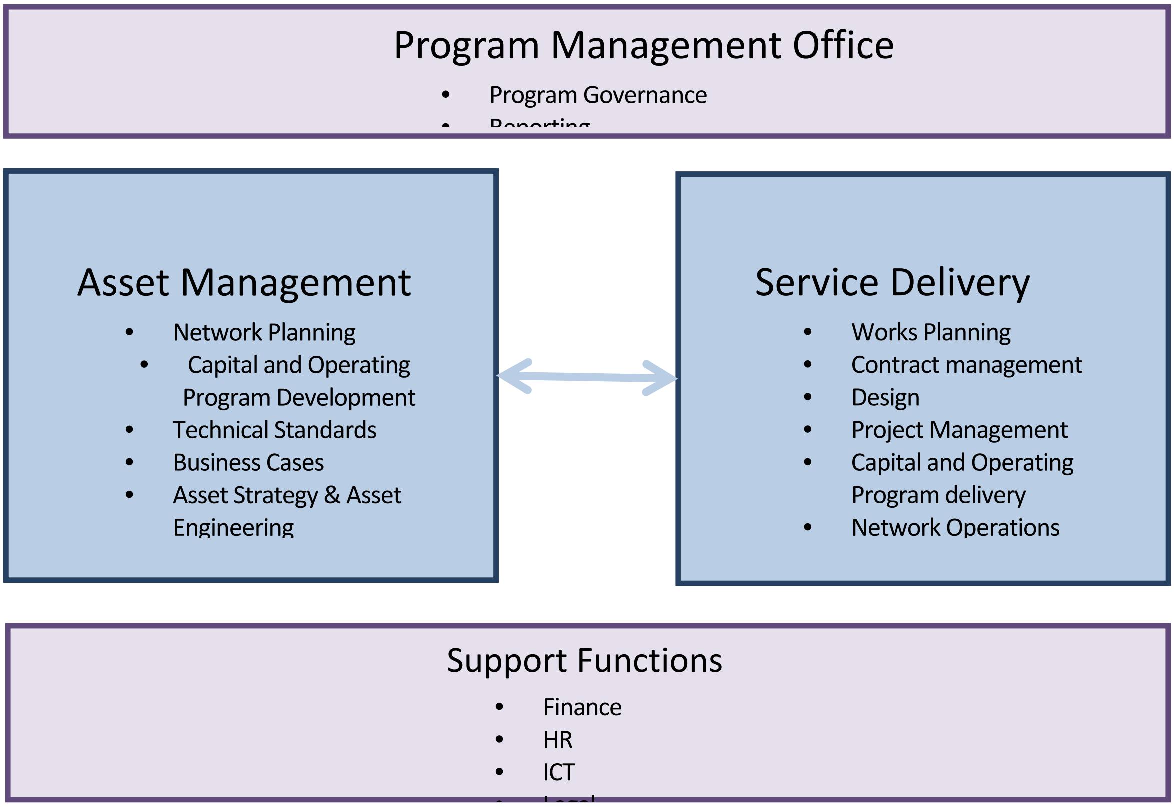

Figure 8 – Simplified Organisational Structure

9.2 Operating Model

Service Delivery utilises a regional based structure with a hybrid operating model to deliver the works program as shown in Figure 9.

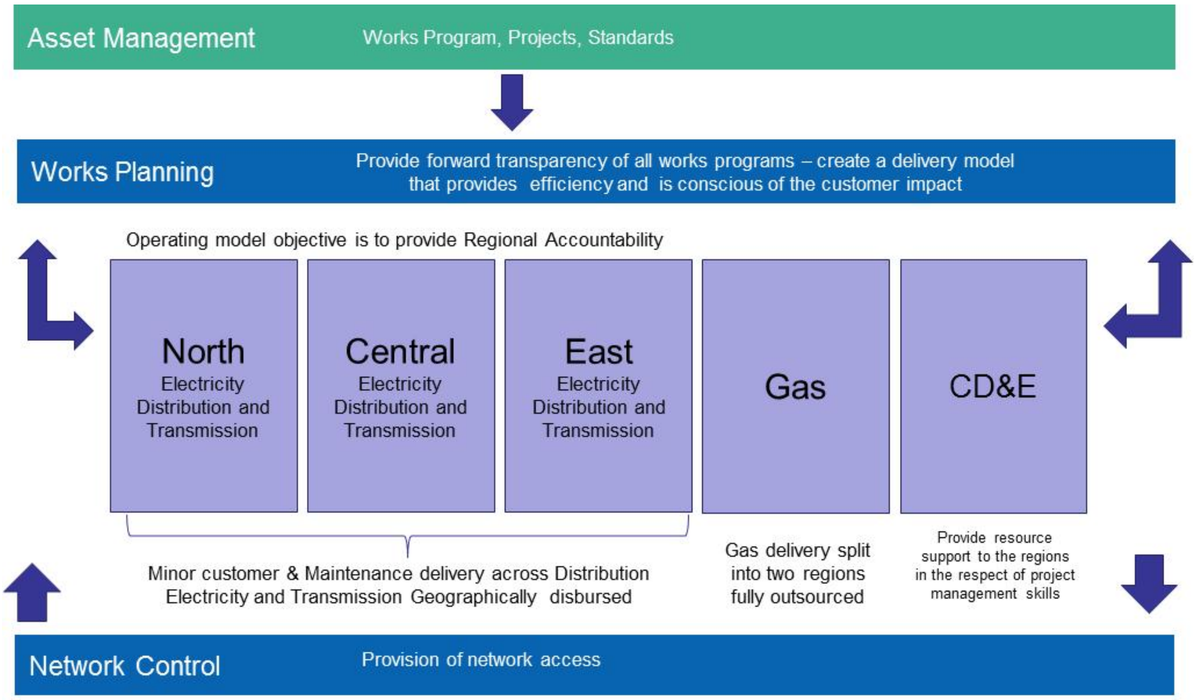

Figure 9 – Service Delivery Regional Operating Model

Each of the regions is accountable for delivery of maintenance and capital works programs. The regions are supported by:

- Network Control by Customer Energy Operations Team (CEOT);
- Works Planning;
- Capital Delivery and Engineering;
- Corporate functions including ICT, Legal and HR.

CEOT incorporates the control room, outage planning and network operations. Works Planning plans the delivery of the complete program and ensures a balance between work volumes and available resources. Capital Delivery and Engineering undertakes design, manages the delivery of major projects such as terminal station rebuild projects, and provides project management support to the regions.

A hybrid operating model is utilised to deliver the program of works. This hybrid involves a mix of internal and external resources. The main elements of the model are:

- Internal teams dedicated to faults, minor capital and customer works;
- A mix of internal and fully outsourced teams by geographic location delivering comparable works programs;
- Capital Panels established to provide top-up resources for minor capital and capital surplus works in each region;
- Major Capital Panels established to facilitate efficient and safe delivery of major works.

The hybrid operating model is shown diagrammatically in Figure 10.

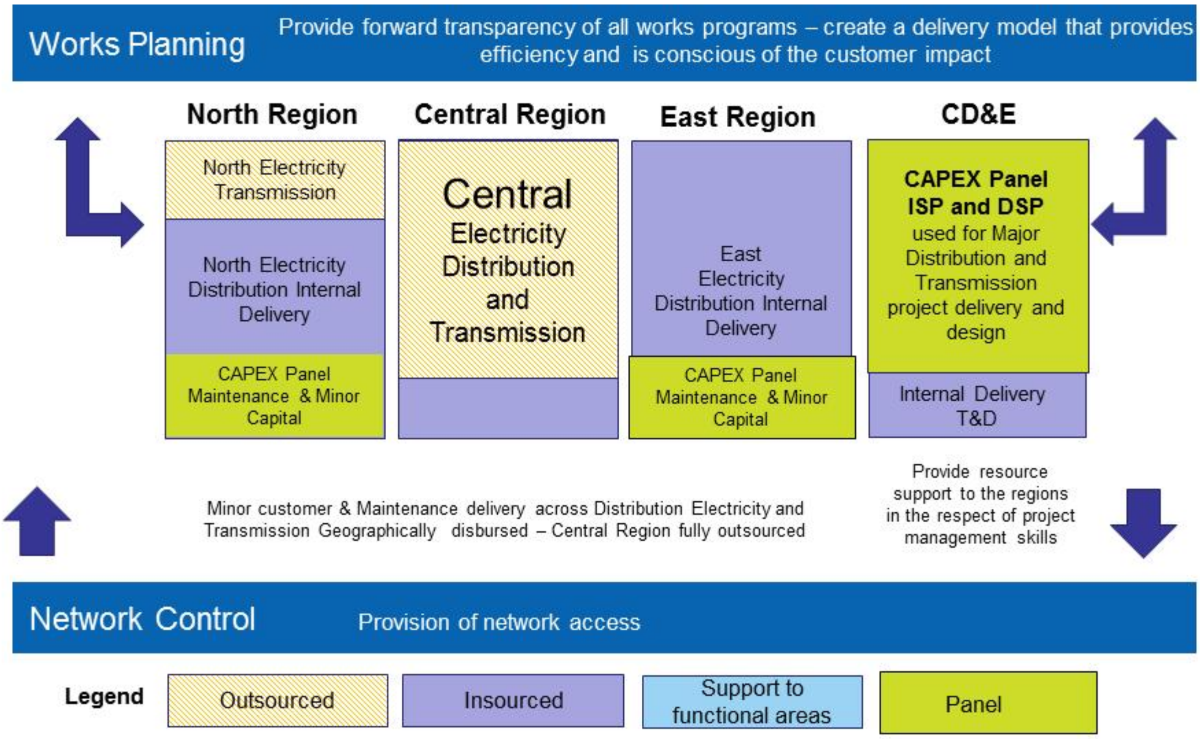

Figure 10 – Service Delivery Regional Operating Model

9.3 Initiatives to improve delivery

Several initiatives have been undertaken to improve the delivery of the works program. These include:

- Enterprise Program Management Office (EPMO) to maintain high planning, reporting and governance standards;
- Selection of Design and Installation Service Providers to a panel of service providers;
- SAP implementation to transition from disparate to integrated solutions enabling works integration.
- SAP Work Manager to deliver integrated programs

The EPMO ensures appropriate governance of projects throughout the project lifecycle and provides consistent project reporting which assists in the delivery of the program and ensures that appropriate action is taken to resolve any project and program issues.

Pre-qualified panels of Design Service Providers (DSPs) and Installation Service Providers (ISPs) have been established to undertake design and installation works for major projects such as zone substation rebuilds. These panels were established by competitive tender and ensure that providers have the skills and resources to undertake the required work in a safe and competent manner and can comply with works management processes.

The implementation of SAP enables works integration involving bundling various types of work by region, location and line. For example, customer works, asset replacements, inspections and defect repairs are bundled together to minimise the impact on customers, reduce the volume of outage applications, and minimising travel time.

SAP Work Manager is the mobility solution complementing delivery of integrated programs by allowing inspection results to be entered directly into the asset management system. This provides field personnel instant access to documents or policies and ability to attach photos of asset condition or completed work while on the job.

9.4 Efficient Delivery

The combination of insourcing and outsourcing provides a sufficient pool of resources to complete the planned program while ensuring flexibility. When peaks of work arise, additional external resources are engaged to meet the peak workload. These additional resources are not retained when the volume of work reduces, ensuring that internal resources are always fully occupied.

The establishment of pre-qualified panels of service providers using a competitive process ensures efficient costs and appropriate quality of services provided. Further, the cost and time taken to engage resources on a project is reduced.

The combination of regions and insourced and outsourced work provide opportunities for comparison and benchmarking of activities including costs, response and quality. This provides a sound basis for improvement of work processes to maximise efficiency.

The integration of both Distribution and Transmission functions provides synergies in areas such as plant procurement, zone substation design, regional management and administrative overheads.

In summary, during the current regulatory period, AusNet Services has successfully delivered a larger capital program than is being proposed for the forecast period. This gives us confidence that our structure, resourcing, processes and governance are sufficiently robust to ensure the forecast program can be delivered. In addition, AusNet Services' demonstrated ability to adapt to an evolving, resource-constrained operating environment in the current period provides further confidence that it is capable of delivering the proposed capital program.

10 Appendix A: RIN Methodology

10.1 Purpose

The purpose of this section is to provide information in relation to information requested in Schedule 1 of the Regulatory Information Notice (RIN) for the forecast period 1 April 2017 to 31 March 2022.

Most of the information requested in Schedule 1 is included in AusNet Services' submission, the appendices to the submission, or in supporting documentation. Information is included in this section where the submission, the appendices to the submission, or the supporting documentation does not provide the information requested in Schedule 1.

This section provides information particularly relevant to the "Replacement Capital Expenditure Modelling" of the RIN.

10.2 Modelling Information

RIN Reference	Commentary
5.1(a)	Asset categories are described in Plant Strategy documents; AMS 10 – 52 to AMS 10 – 79, Planning Reports for Terminal Station rebuild projects and Program of Work documents. Further explanation of the asset categories included in template 2.2 is provided below. TRANSMISSION TOWERS – OTHER The expenditure in this section refers to upgrade of 48 transmission towers to the current tower design code, AS/NZS 7000 along the Murray Switching Station (MSS) to Dederang Terminal Station (DDTS) numbers 1 and 2 - 330kV lines. For more information refer to 2017-22 Program of Works – MSS-DDTS 1 and 2- 330kV lines Tower Upgrade Program CONDUCTORS – OTHER The expenditure in this category for the last two years of the current reset period includes replacement of 10 kilometres route length of conductors. This is a program started in the current regulatory period to replace selected worst condition conductor spans posing high risk. SUBSTATION REACTIVE PLANTS – OTHER Although AusNet Services does not plan to replace the entire reactive plant at any individual station during the forecast regulatory period, some component part replacements will be required to maintain services. The expenditure proposed for the forecast regulatory period includes replacement of selected worst condition air core reactors, thyristor switched reactor/capacitor wall bushings, etc. More information is available in 2017-22 Program of Works - Reactive Plant Replacement. The expenditure for the last two years of the current regulatory period includes ongoing work for refurbishment of synchronous condensers. Reactive plants provide essential dynamic reactive support to the network. COMMUNICATION NETWORK ASSETS For more information refer to 2017-22 Program of Works - Safety and Security of Communications Assets, 2017-22 Program of Works - Communication Network Supporting Infrastructure and Systems, 2017-22 Program of Works - Communication Network Bearers, 2017-22 Program of Works - Communication Network Technologies and AMS 10-56 Communication Systems. SECONDARY ASSETS (PROTECTION/CONTROL/SCADA/METERING) For more information refer 2017-22 Program of Works - Secondary Systems and AMS 10-68 Secondary Systems. POWER TRANSFORMERS – BUSHING REPLACEMENT Refer to 2017-22 Program of Works – Transformer Bushing Replacements

RIN Reference	Commentary
	POWER TRANSFORMERS – LIFE EXTENSION Refer to 2017-22 Program of Works - Transformer Life Extension POWER TRANSFORMERS – IMPROVED SAFE ACCESS Refer to 2017-22 Program of Works - Transformer Improved Safe Maintenance Access ON-LINE MONITORING Refer to 2017-22 Program of Works – Circuit Breaker Online Monitoring FIRE PROTECTION SYSTEMS Refer to 2017-22 Program of Works - Fire Protection System Replacement CIVIL INFRASTRUCTURE Refer to 2017-22 Program of Works - Civil Infrastructure Replacement INFRASTRUCTURE SECURITY Refer to 2017-22 Program of Works - Security System Infrastructure Replacement STRUCTURE FALL ARRESTS (STATIONS) Refer to 2017-22 Program of Works - Rack Structures: Fall Arrest Installation EARTH WIRES Refer to 2017-22 Program of Works - Transmission Line Conductor and Groundwire Replacement Program INSULATORS Refer to 2017-22 Program of Works - Transmission Line Insulator Replacement TOWER FALL ARRESTS Refer to 2017-22 Program of Works – Structures (Towers): Fall Arrest Installation Program AusNet Services asset replacement/refurbishment programs are based on asset condition, location criticality, safety risks due to particular type issues etc but not on the age, though asset age can be a contributing factor. In most of the cases total asset replacement is the most economic option. Wherever it is not, for example in the case of disconnectors, bushing replacements of transformers, etc, AusNet Services' approach is to select the most appropriate option resulting lowest cost to the customers while extending the useful asset life.
5.1(b)(i)(ii)	AusNet Services uses condition, not age-based, probability distributions to forecast asset replacement volumes. The methods used to forecast asset replacements are detailed in the Plant Strategies and summarised in this document. The replacement life statistics were based on recorded disposal life of the assets extracted from AusNet Services' Asset Management systems.
5.1(b)(iii)	AusNet Services considers that a normal distribution should be used to simulate the replacement needs of an asset category unless appropriate information is available to develop a more appropriate distribution. Our experience is that the detailed information is rarely available to develop a more appropriate distribution and therefore factors such as the skewness of the distribution cannot be properly considered. Most asset categories in Template comprise a mix of assets including differing material types, manufacturers and technologies. For example, circuit breakers in a specified voltage range are likely to comprise a variety of technologies. Further, the rate of condition deterioration of assets is dependent upon the environment and operating conditions. A circuit breaker used for capacitor bank switching has higher duty cycle compared to a circuit breaker in a feeder. The typical age when the 'wear out' phase becomes evident will depend upon these factors and the asset condition monitoring methodology. Any process to verify that the parameters are a reasonable estimate of life should consider available data and experience. For example, if the estimated life is based on recorded age at asset disposal, consideration should be given to factors such as the proportion of assets that are replaced for reasons other than end of effective life and asset design life.

RIN Reference	Commentary
5.1(c) (ii) (iii) (iv) (v)	The derivation of unit costs is detailed in Appendix – Unit Rates. Double counting has been avoided by developing the forecast in asset categories consistent with AusNet Services' budget process and by explicitly accounting for potential double counting. For example, the program of circuit breaker replacement identifies those breakers located in stations which are subject to 'rebuild' projects and removed these from the program. The same approach was taken with other asset categories such as Secondary systems. Variability in unit costs will occur in all asset categories. The variability arises from many factors such as location, terrain, material type, structure complexity, and emergency vs planned replacement. The derivation of unit costs is described in the Unit Rates document. The unit costs for most assets have been derived from recent projects where equipment and labour components have been competitively tendered. The forecast programs are extensions of current programs and therefore the historical unit rates should provide a reasonable estimate of future unit costs.

Table 41 – RIN Modelling Information Table