AusNet Transmission Group Pty Ltd

Transmission Revenue Review 2017-2022

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Planning Report Project XA14

West Melbourne Terminal Station Redevelopment

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1 Executive Summary

1.1 Responsibility

AusNet Transmission Group (AusNet Services) as a Transmission Network Service Provider (TNSP) in the state of Victoria has the ownership, operation and maintenance responsibility for West Melbourne Terminal Station (WMTS). TNSP obligations include maintaining a safe working environment for staff and contractors, maintaining the quality, reliability and security of customer supplies, and preventing operating and maintenance costs from escalating to inefficient levels.

1.2 Emerging Constraints

WMTS was developed in the early 1960's to support the growing load in West Melbourne and the surrounding areas and to also secure electricity supplies to the growing Melbourne Central Business District (CBD). Many of the electricity assets at WMTS are around 50 years old and condition assessments indicate that several assets are approaching the end of their technical lives. The emerging service constraints are:

- Health and safety risks presented by a possible explosive failure of 220 kV circuit breaker bushings, 66 kV instrument transformers, 66 kV bulk oil circuit breakers, transformer bushings or 22 kV switchboards;
- Security of supply risks presented by a failure of the 220/66 kV transformers, 220 kV circuit breakers, 66 kV circuit breakers or 22 kV switchboards;
- Collateral plant damage risks presented by an explosive failure of a transformer bushing, 66 kV instrument transformer, 66 kV bulk oil circuit breaker bushing or 22 kV switchboard;
- Environmental risks associated with insulating oil spill or fire.

1.3 Previous TRR Proposal

In the revenue proposal for the 2014-17 period, AusNet Services proposed to redevelop WMTS using indoor Gas Insulated Switchgear (GIS) technologies, due to space constraints on the site.

During the course of the previous review, the Linking Melbourne Authority (LMA) notified AusNet Services that it might compulsorily acquire part of the land at the WMTS site to enable the development of the East West Link (EWL). This further constrained the space available on the site.

In the current period several exogenous changes have led AusNet Services to review the economic timing and design of the WMTS redevelopment. The exogenous changes include new value of customer reliability (VCR) rates following AEMO's survey, the new demand forecast for WMTS, which also takes into consideration CitiPower's plan to retire the 22 kV supply at WMTS, as well as the cancelation of the proposed EWL.

The above changes in key planning assumptions and the easing of site space constraints have enabled AusNet Services to defer the WMTS redevelopment project and change the redevelopment to adopt lower cost Air Insulated Switchgear (AIS) technology.

1.4 Economic Option

The planning and design review of the WMTS redevelopment considered the following credible options to address the service constraints and to meet the long term planning requirements for WMTS outlined in the Victorian Annual Planning Report and Transmission Connection Planning Report:

- Business as usual to define the baseline risk;
- Non network option of embedded generation and/or demand side response;
- Run to failure and replace assets upon failure;

- Redevelopment with Air Insulated Switchgear (AIS);
- Redevelopment with Gas Insulated Switchgear (GIS)

The most economic option to address the emerging constraints at WMTS is a redevelopment with AIS that replaces all deteriorating assets and addresses all emerging risks. This option has the lowest present value cost ($108 M) and is consistent with the future development plans for WMTS. The economic timing for project completion is 2021 with an estimated total capital cost of $118.8 M ($101.5 M direct $2015).

2 Purpose

This planning report outlines asset condition, asset failure risks and network development plans relevant to WMTS for the period from 2015/16 to 2024/25. It provides an analysis of viable options to address the identified risks and maintain the efficient delivery of electrical energy from WMTS consistent with the National Electricity Rules (NER) and stakeholder's requirements. It also summarizes the scope, delivery schedule and expenditures associated with the most economical solution to emerging constraints.

3 Regulatory Obligations and Customer Requirements

This planning report acknowledges AusNet Services' obligations as a TNSP under the National Electricity Rules with particular emphasis on:

Clause 6A.6.7 of the National Electricity Rules requires AusNet Services to propose capital expenditures necessary to:

(1) meet or manage the expected demand for prescribed transmission services over that period;

(2) comply with all applicable regulatory obligations or requirements associated with the provision of prescribed transmission services;

(3) to the extent that there is no applicable regulatory obligation or requirement in relation to:

- *(i) the quality, reliability or security of supply of prescribed transmission services; or*
- *(ii) the reliability or security of the transmission system through the supply of prescribed transmission services,*

to the relevant extent:

- *(iii) maintain the quality, reliability and security of supply of prescribed transmission services; and*
- *(iv) maintain the reliability and security of the transmission system through the supply of prescribed transmission services; and*

(4) maintain the safety of the transmission system through the supply of prescribed transmission services.

The Electricity Safety Act (section 98(a)) requires AusNet Services to "design, construct, operate, maintain and decommission its supply network to minimise the hazards and risks, so far as is practicable, to the safety of any person arising from the supply network; having regard to the:

a) severity of the hazard or risk in question; and

b) state of knowledge about the hazard or risk and any ways of removing or mitigating the hazard or risk; and

c) availability and suitability of ways to remove or mitigate the hazard or risk; and

d) cost of removing or mitigating the hazard or risk".

4 Background

WMTS is located northwest of Melbourne's CBD and supplies the western Central Business District, including Docklands areas, as well as the inner suburbs of Northcote and Brunswick West in the north, and Kensington, Flemington, Footscray and Yarraville in the west.

WMTS is the key terminal station supplying Melbourne's CBD and inner suburban areas and is connected in the western metropolitan 220 kV ring as shown in Figure 1.

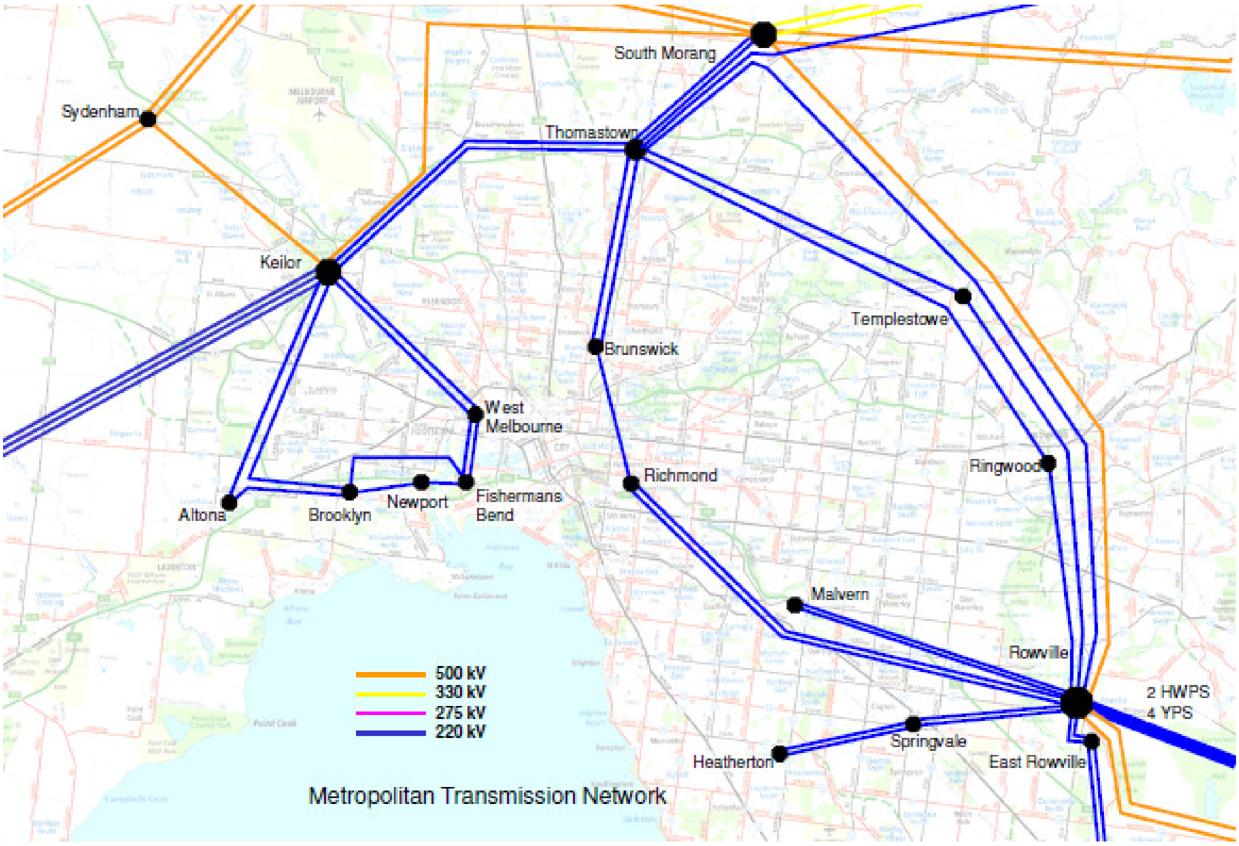

Figure 1 – Metropolitan Melbourne Transmission Network

WMTS is established on a small landlocked site and is located in a suburb, which is undergoing urban renewal[1]. The 220 kV switching configuration is non-standard with most circuits connected with only one circuit breaker to a single bus. This is different to the standard breaker and half or double bus switching configurations normally used for transmission voltages of 220 kV or higher.

1 Arden-Macaulay Structure Plan, 2012, City of Melbourne

Figure 2: Aerial view of WMTS

The WMTS 220 kV switchyard connects two lines from Keilor and two lines from Fishermans Bend Terminal Station. Transformation at WMTS comprise four 150 MVA 220/66 kV and two 165 MVA 220/22kV transformers to supply both 66 kV and 22 kV outgoing feeders; providing connection services to CitiPower and Jemena.

The 66 kV switchyard includes eleven feeders, three AIS buses, one GIS bus and two 50 MVAr capacitor banks. Most of the 66 kV circuit breakers are bulk oil circuit breakers manufactured in the mid-1960s.

The 22 kV switchroom supplies nine feeders. CitiPower plans to upgrade and reconfigure the WMTS 22 kV distribution network, which will enable retirement of the 22 kV assets at WMTS.

Figure 3, below shows the present configuration at WMTS.

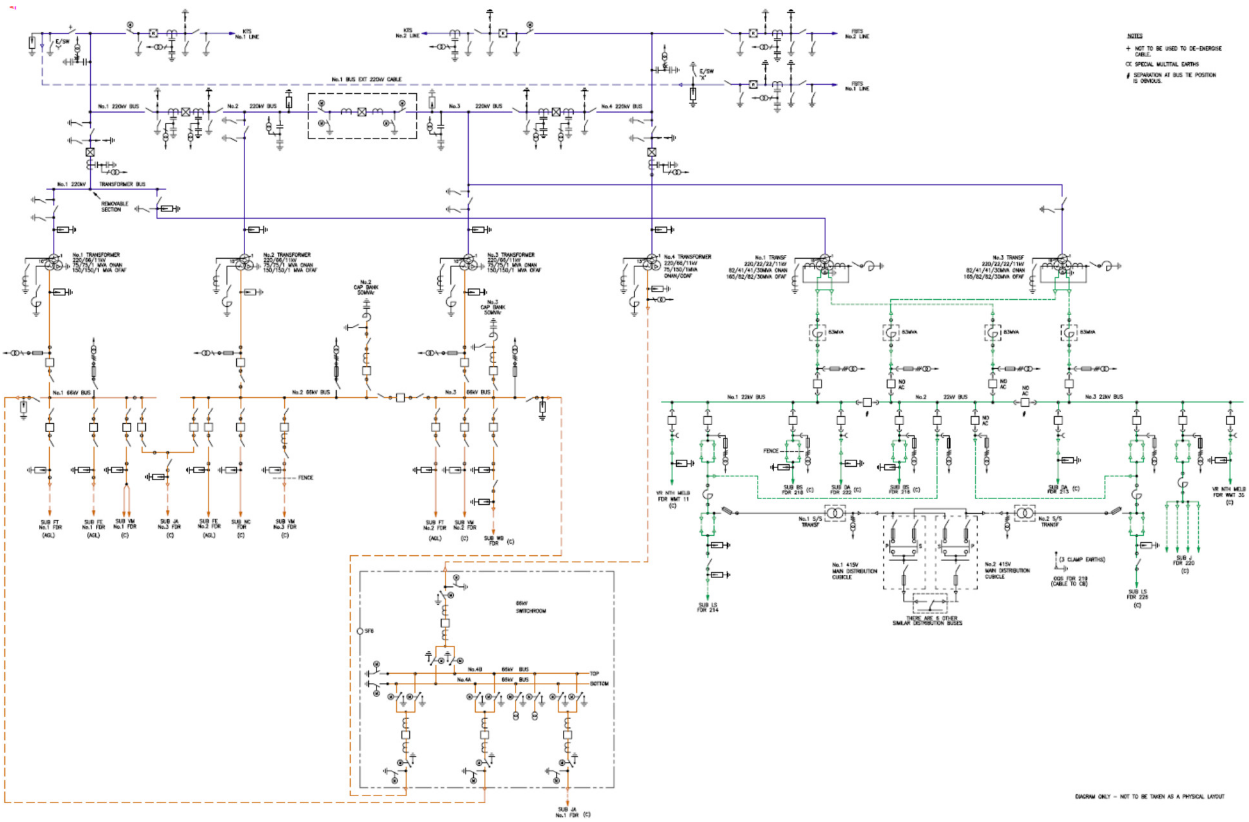

Figure 3 – Single Line Diagram of WMTS

Many of the primary and secondary assets installed at the time that WMTS was established have deteriorated and are reaching the end of their technical lives. The risks associated with plant failure are increasing and these assets are becoming more difficult and expensive to maintain due to a lack of manufacturer support and a scarcity of spare parts.

5 Previous TRR Proposal

In the revenue proposal for the 2014-17 period, AusNet Services proposed to redevelop WMTS using indoor Gas Insulated Switchgear (GIS) technologies, due to space constraints on the site.

During the course of the previous review, the Linking Melbourne Authority (LMA) notified AusNet Services that it might compulsorily acquire part of the land at the WMTS site to enable the development of the East West Link. This further constrained the space available on the site.

AusNet Services revised its proposed project to enable it to proceed regardless of whether or not the land earmarked for compulsorily acquisition was subsequently acquired. This was a prudent approach as economic studies supported the project commencing in 2014 and it also recognises the significant uncertainty associated with the East West Link development.

5.1 Exogenous changes that have impacted the project's economic timing and design

In the current period several exogenous changes have led AusNet Services to review the economic timing and design of the WTMS redevelopment. A change in key planning assumptions and the easing of site space constraints have enabled AusNet Services to defer the project and change the redevelopment to adopt lower cost Air Insulated Switchgear (AIS) technology.

The changes that have impacted the project are explained in more detail below.

5.1.1 Easing Space Constraints

During the previous review, the space available to undertake the rebuild on the WMTS site was severely constrained, leading to the use of more compact (but more costly) GIS technology being the only feasible solution.

The East West Link alignment and construction zone encroached on the WMTS site, meaning that this land would have been unavailable to AusNet Services during the WMTS redevelopment construction period. The cancellation of the East West Link means that this land is available for AusNet Services' use. However, while AusNet Services will utilise the EWL construction zone during the WMTS project, the solution has been designed to avoid locating assets on the footprint of the EWL. This is because the WMTS assets have 50 to 70 year lives, and it is prudent to consider the implications should the EWL proceed over this time period. This design decision has not added to the total cost of the WMTS project.

AusNet Services has been successful in obtaining the long term lease (60 years) of additional land adjacent to the existing WMTS site in the VicTrack land between the terminal station and the railway lines. This has opened up the opportunity to redevelop the existing 220 kV switchyard with AIS switchgear. Additionally the greater certainty of the completion of Brunswick Terminal Station (BTS) in 2016 will reduce the 66 kV load at WMTS temporarily and reduce 66 kV exit requirements[2]. These changes have created a window of opportunity in which an AIS replacement project is feasible post BTS completion and prior to 22 kV asset retirements when some of the WMTS 22 kV load will be transferred to WMTS 66 kV.

In addition CitiPower has indicated that it is economic to retire the 22kV supply from WMTS, partly due to the savings AusNet Services will realise by no longer needing to replace the 22 kV assets (transformers, switchroom and fault limiting reactors). This development has also contributed to the feasibility of the AIS technology and for the ultimate plan for WMTS to be still achievable despite the larger footprint required for AIS.

The above changes have been critical in enabling the project to proceed using AIS technology, as it enables a brownfield type redevelopment of the 220 kV switchyard with AIS, and for the first replacement assets to be constructed without impacting on the reliability of the supply from this key connection station.

These changes in the land availability are illustrated in the aerial photo of the WMTS site below.

[2] The Moreland city council approved the planning permit for the project to augment BTS and work has started on site. The project is expected to be completed by end 2016, which will enable significant load (five 66 kV zone substations) transfers from WMTS to BTS. Additional load transfers from WMTS to BTS of up to 90 MVA will be possible in the event of a major contingency at WMTS.

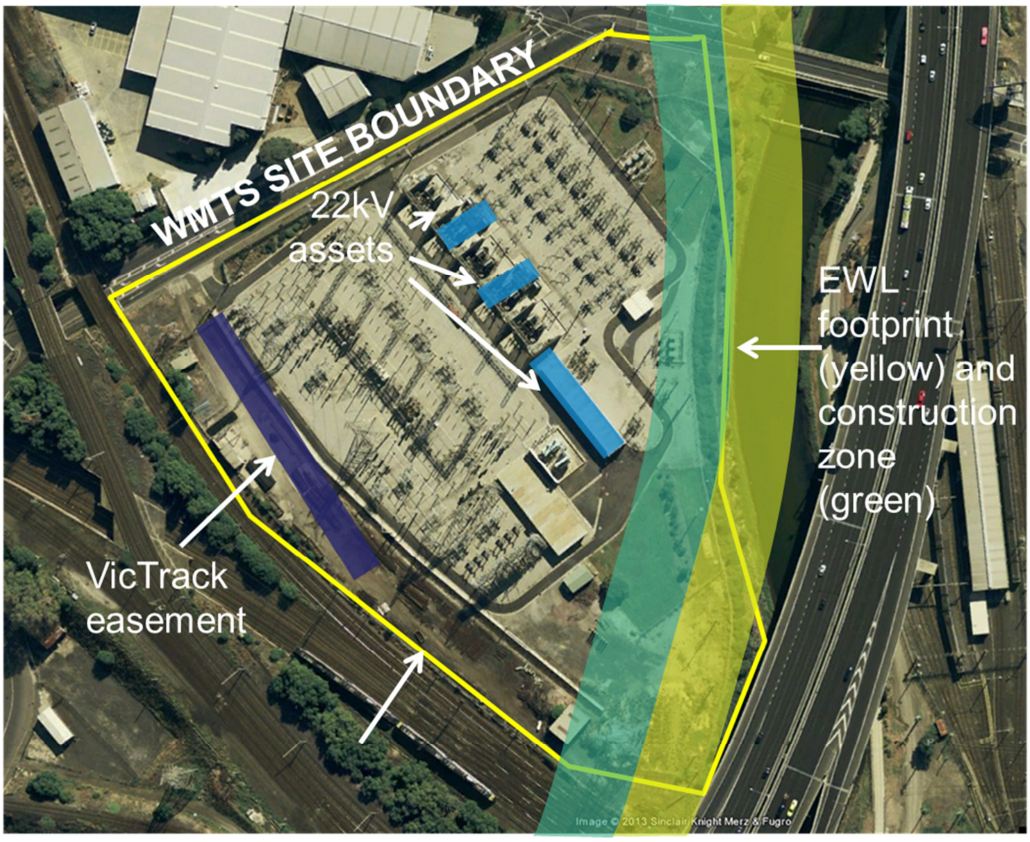

Figure 4: Changes to WMTS site land availability

5.1.2 Change in Key Planning Assumptions

AEMO has published new VCR rates for Victoria in September 2014 following a customer survey that has been carried out on a NEM-wide basis. The Victorian composite VCR rate for all sectors has changed from $63.09/kWh to $39.50/kWh[3] and is now being used in planning studies. The new VCR rate for WMTS, based on the WMTS load composition, is $42/kWh compared with the old VCR rate of $99.62/kWh. The extensive change in VCR has been unexpected and presents a significant reduction (2.37 times) in the monetised supply risk at WMTS[4].

AEMO has for the first time produced their own demand forecast for the Victorian connection stations; distinct from the traditional terminal station demand forecast produced by the Victorian distribution businesses. AEMO's demand forecast for WMTS is substantially lower than the forecast prepared by the distribution businesses. AEMO's demand forecast shows that demand is not forecast to grow for the period up to 2023/24 following load transfers from WMTS to BTS.

CitiPower plans to retire the 22 kV supply from WMTS in stages with the last circuit breakers to be retired by end 2020. CitiPower's plan is to transfer the WMTS 22 kV load to both BTS 66 kV and WMTS 66 kV. All 22 kV assets, including the 22 kV switchboards, 22 kV building, 220/22 kV transformers and 22 kV fault limiting reactors, can be retired from WMTS once the load transfers have been completed.

The augmentation of BTS with three 225 MVA 220/66 kV transformers is forecast to be completed by end 2016, which will allow load transfers from WMTS to BTS to be completed before summer 2017/18.

The lower VCR rate for WMTS, greater certainty of the timing of load transfers from WMTS to BTS and AEMO's demand forecast that shows flat demand growth over the ten year planning period suggest that the proposed redevelopment of WMTS with 220 kV and 66 kV GIS is no longer economic in the original time frames.

[3] AEMO's 2014 VCR survey results shows a reduction of more than 60% in the VCR rate for commercial and agricultural load, and a 37% reduction in the state average VCR rate for all sectors excluding direct connected customers.

[4] The monetised supply risk is calculated by weighing the energy at risk with the VCR based on the load composition at the particular connection station.

6 Planning Considerations

6.1 Planning Responsibilities

The augmentation responsibility for WMTS lays with the Australian Energy Market Operator (AEMO) for the shared transmission network and with the distributors, Jemena and CitiPower, for the transmission connection assets.

6.2 Demand

WMTS 66 kV is a summer peaking station. Figure 5 below shows both the Distribution Network Service Provider (DNSP) and AEMO forecast demand for WMTS 66 kV for Summer POE10 and POE50 conditions. The DNSP demand forecast shows demand growth at an average annual rate of 3.3% and 1.5% for the Summer POE10 and POE50 forecasts respectively following load transfers to BTS. AEMO forecast demand growth to be flat over the planning period following load transfers to BTS.

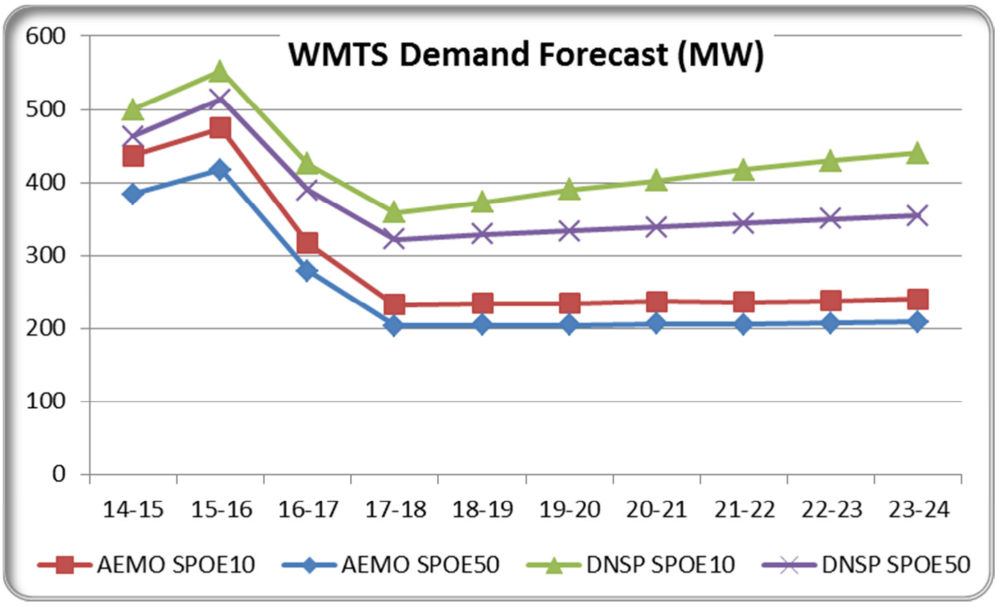

Figure 5: DNSP and AEMO Demand forecast for WMTS 66 kV

6.3 Future Planning Requirements

Any significant asset replacements at WMTS must consider the longer term shared network and connection network development plans of other parties to ensure individual decisions will not compromise security of supply or impede economic future capacity augmentation. AusNet Services' redevelopment project accommodates AEMO and the distributors' future plans for WMTS, which include the following:

- Four 225 MVA 220/66 kV transformers
- Possible new 220 kV circuit connections
- Five feeder and one capacitor 66 kV circuit breaker per 66 kV bus
- Retirement of the 22 kV supply from WMTS.

7 Asset Condition

AMS 10-13 Condition Monitoring describes AusNet Services' strategy and approach to monitoring the condition of assets as summarised in this section. Asset condition is measured with reference to an asset health index, on a scale of C1 to C5. The C1 to C5 condition range is consistent across asset types and relates to the remaining service potential. The table below provides a simple explanation of the asset condition scores.

Condition Score	Likert Scale	Condition Description	Recommended Action	Remaining Service Potential%
C1	Very Good	Initial Service Condition	No additional specific actions required, continue routine maintenance and condition monitoring	95
C2	Good	Better than normal for age or refurbished		70
C3	Average	Normal condition for age		45
C4	Poor	Advanced Deterioration	Remedial action/replacement within 2-10 years	25
C5	Very Poor	Extreme deterioration approaching end of life	Remedial action/replacement within 1-5 years	15

Table 1 – Condition Score and Remaining Service Potential

Asset condition is the main driver for this project. The condition of the key assets at WMTS is discussed in the Asset Health Reports for the key asset classes such as power transformers, instrument transformers and switchgear with information on asset condition rankings, recommended risk mitigation options and replacement timeframes.

7.1 220/66 kV Power Transformers

AMS 10-141[5] identifies a number of [C-I-C] 150 MVA 220/66 kV transformers at various terminal stations that display a high level of internal deterioration, which is predominantly due to:

- High average loading and operating temperatures during periods of high ambient temperatures;
- Ineffective operation of the insulating oil circulation and air cooling systems.

Deterioration of the winding primary insulation system is well advanced in these transformers and refurbishment of the core and coils is no longer a cost effective option. Asset Health Index scores ranging from C5 to C4 have been assigned to the core and coils of the B1, B2, B3 and L1 transformers as a result of their poor condition. They are of similar specification to those discussed in AMS 10-141 and exhibit the same deterioration characteristics. AusNet Services has outlined the objective to maintain a sustainable risk position for the next decade with respect to power transformers in AMS 10-67[6].

Table 2 shows the condition scores for each component of the four 220/66 kV and two 220/22 kV transformers at WMTS. The B3 Transformer that has been assessed at C5 has an expected failure rate of 4.7%, whilst the transformers with C4 Asset Health Index scores have an expected failure rate of 3.4%.

5 AMS 10-141 Asset Health Review for Power Transformers in Terminal Stations .

6 AMS 10-67 Power Transformers & Oil-filled Reactors.

DESCRIPTION	MANUFACTURER	INSTALL YEAR	ASSET CONDITION	Core & Windings	Bushings	Oil	Tap Changer	Tank/Aux
B1 220/66KV TRANSFORMER	[C-I-C]	1965	C4	C4	C5	C3	C4	C4
B2 220/66KV TRANSFORMER	[C-I-C]	1968	C4	C4	C4	C3	C4	C4
B3 220/66KV TRANSFORMER	[C-I-C]	1964	C5	C5	C5	C4	C4	C4
B4 220/66KV TRANSFORMER	[C-I-C]	2001	C1	C1	C1	C1	C1	C2
L1 220/22KV TRANSFORMER	[C-I-C]	1964	C4	C4	C2	C3	C4	C4
L3 220/22KV TRANSFORMER	[C-I-C]	1964	C3	C3	C2	C3	C4	C5

Table 2 – Transformer Condition Score

A major transformer failure as result of a winding failure, major tap changer failure or bushing failure resulting in an extended transformer outage of months for major repairs or replacement is estimated to have a probability of between 5.2% to 6.8% over the 2017 to 2023 period.

7.2 220 kV Circuit Breakers

There are five [C-I-C] minimum oil circuit breakers in the 220 kV switchyard, which are approaching the end of their technical life. The circuit breaker strategy AMS 10-144[7] identifies this type of circuit breaker amongst the oldest in AusNet Services' 220 kV circuit breaker fleet. [C-I-C] circuit breakers are of a minimum-oil type interrupter design with a spring type mechanism, which is now considered an obsolete design with no original equipment manufacturer support. This type of circuit breakers have generally provided reliable service, however deterioration is now measurable and they are becoming less reliable as they exhibit a range of service age and duty related defects. Consequently their replacement is considered when scoping economic station redevelopment projects. Recent failures of these type of circuit breakers are shown in Table 3 below.

Incident Date	Station	kV	CB Manuf.	CB Designation	Technology	Duty	Age (years) at time of failure	Nature of Failure	Remedial Action	Incident Year
24/01/2000	HTS	220	Sprecher & Schuh	HPF514P/6A	Minimum Oil	Transf./Line/ Bus Tie	34	Partial close operation. Drive insulators fractured.	Replaced broken drive insulators. Class 2 overhaul on interrupters	2000
19/04/2002	KTS	220	Sprecher & Schuh	HPF514P/6A	Minimum Oil	Transf./Line/ Bus Tie	40	Partial close operation. Drive insulators fractured.	Replaced broken drive insulators. Class 2 overhaul on interrupters	2002
22/03/2010	BLTS	220	Sprecher & Schuh	HPF514Q/4D	Minimum Oil	Transf./Line/ Bus Tie	35	Partial close operation, external linkages seized causing drive insulators fracture.	Replace broken drive insulators. Improved maintenance regime.	2010
14/12/2010	SVTS	220	Sprecher & Schuh	HPF514P/6A	Minimum Oil	Transf./Line/ Bus Tie	44	Partial close operation. Drive insulators flange mortar crumbled.	Replaced broken drive insulators.	2010
31/08/2011	BLTS	220	Sprecher & Schuh	HPF514Q/4D	Minimum Oil	Transf./Line/ Bus Tie	36	Failure to close on one phase as mechanism seized through internal corrosion.	Replaced broken drive insulators. Class 2 overhaul on interrupters	2011

Table 3 – 220 kV Circuit Breaker Failures

The [C-I-C] Hybrid Insulated Switchgear (HIS) has a faulty control system, which is no longer supported by the supplier. It has had numerous failures and has been assessed as a high risk of failure.

7 AMS 10-144 Asset Health Review for Transmission Circuit Breaker.

CIRCUIT	MANUFACTURER	AGE	ASSET CONDITION
NO.1 220KV TRANS BUS CB AT WMTS	SPRECHER & SCHUH	46	C5
2-3 220KV BUS TIE CB AT WMTS	SIEMENS	13	C5
FBTS NO.2 220KV LINE CB AT WMTS	SPRECHER & SCHUH	43	C4
KTS NO.2 220KV LINE CB AT WMTS	ASEA	29	C4
1-2 220KV BUS TIE CB AT WMTS	SPRECHER & SCHUH	46	C4
3-4 220KV BUS TIE CB AT WMTS	SPRECHER & SCHUH	46	C4
FBTS NO.1 220KV LINE CB AT WMTS	SPRECHER & SCHUH	43	C3
KTS NO.1 220KV LINE CB AT WMTS	ASEA	29	C3
B4 TRANS 220KV CB AT WMTS	ABB	11	C1

Table 4 – 220 kV Circuit Breaker Condition Score

7.3 220 kV Voltage Transformers

The two [C-I-C] voltage transformers are of an obsolete design and have been assessed as C3/C4.

Location	MANUFACTURER	Year	Condition
NO.4 220KV BUS CVT AT WMTS	[C-I-C]	1964	C4
NO.1 220KV BUS CVT AT WMTS	[C-I-C]	1964	C3
NO.2 220KV BUS CVT AT WMTS	[C-I-C]	2001	C2
NO.3 220KV BUS CVT AT WMTS	[C-I-C]	2001	C2
KTS NO.1 220KV LINE CB CVT R/PH AT WMTS	[C-I-C]	2007	C1
B4 220/66KV TRANS 220KV CVD R/PH AT WMTS	[C-I-C]	2012	C1
B4 220/66KV TRANS 220KV CVD W/PH AT WMTS	[C-I-C]	2012	C1
B4 220/66KV TRANS 220KV CVD B/PH AT WMTS	[C-I-C]	2012	C1
FBTS NO.1 220KV LINE CVT R/PH AT WMTS	[C-I-C]	2012	C1
FBTS NO.2 220KV LINE CVT R/PH AT WMTS	[C-I-C]	2012	C1

Table 5 – 220 kV Voltage Transformer Condition Score

7.4 66 kV Circuit Breakers

Most of the 66 kV circuit breakers at WMTS are of bulk-oil technology, manufactured by [C-I-C]. They are amongst the oldest circuit breakers installed in the network, ranging in service age from 44 to 50 years old. Asset Management Strategy AMS 10-106[8] provides a summary of the key issues of these type of bulk oil circuit breakers, which includes the following:

- Age/duty related deterioration including the erosion of arc control devices, bushing oil leakages, and wear of operating mechanisms and drive systems;
- Limited fault level capability requiring restrictive switching configurations;
- Maintenance intensive;
- Manufacturer no-longer provides technical support or spares;
- Insufficient oil bunding.

8 AMS 10-106 Circuit Breakers.

CIRCUIT	MANUFACTURER	AGE	ASSET CONDITION
JA NO.3 66KV FDR NO.1 BUS CB AT WMTS	[C-I-C]	29	C5
1-4A/4B 66KV BUS TIE CB AT WMTS	[C-I-C]	13	C5
JA NO.1 66KV FDR CB AT WMTS	[C-I-C]	9	C5
FT NO.2 66KV FDR CB AT WMTS	[C-I-C]	48	C4
FT NO.1 66KV FDR CB AT WMTS	[C-I-C]	44	C4
FE NO.1 66KV FDR CB AT WMTS	[C-I-C]	45	C4
JA NO.3 66KV FDR NO.2 BUS CB AT WMTS	[C-I-C]	50	C4
NC 66KV FDR CB AT WMTS	[C-I-C]	45	C4
VM NO.2 66KV FDR CB AT WMTS	[C-I-C]	48	C4
VM NO.1 66KV FDR CB AT WMTS	[C-I-C]	48	C4
VM NO.3 66KV FDR CB AT WMTS	[C-I-C]	34	C4
WB 66KV FDR NO.3 BUS CB AT WMTS	[C-I-C]	47	C4
FE NO.2 66KV FDR CB AT WMTS	[C-I-C]	45	C4
B1 TRANS 66KV CB AT WMTS	[C-I-C]	49	C4
B2 TRANS 66KV CB AT WMTS	[C-I-C]	50	C4
2-3 66KV BUS TIE CB AT WMTS	[C-I-C]	50	C4
NO.3 66KV CAPACITOR BANK CB AT WMTS	[C-I-C]	17	C4
B3 TRANS 66KV CB AT WMTS	[C-I-C]	50	C4
NO.2 66KV CAPACITOR BANK CB AT WMTS	[C-I-C]	19	C4
B4 TRANS 66KV CB AT WMTS	[C-I-C]	13	C4
3-4A/4B 66KV BUS TIE CB AT WMTS	[C-I-C]	13	C4

Table 6 – 66 kV Circuit Breaker Condition Score

7.5 Secondary Systems

The protection and control systems at WMTS consist of varied technologies. Some of the electromechanical type relays originally installed are still in service. Over the years, protection system upgrades for specific primary assets have been necessary, resulting in the existence of first generation digital relays.

When a project for installation of the new B4 transformer was completed in 2005, newer digital protection systems and a SCIMS (Station Control and Information Management System) compatible Remote Terminal Unit (RTU) with corresponding Human Machine Interface (HMI) were installed at WMTS in the same project. Protection systems replaced after this project have digital relays interfaced to the SCIMS based RTU. These changes have resulted in a hybrid configuration of protection systems as well as control systems. Different generations of relays from electromechanical types to digital numerical types are now in use at WMTS. Remote control functions are provided by a mix of obsolete C2020 RTU and SCIMS compatible RTU.

Local control is provided by a station HMI as well as mimic panels. The electromechanical and first generation digital relays and C2020 RTU have reached the end of their technical lives. Interfacing the existing equipment with new protection systems or SCIMS compatible RTU will further complicate the configuration of protection and control systems at WMTS and increase the associated operation and maintenance costs and risks. The obsolete protection systems, RTUs and mimic panels should be replaced in a station rebuild project, or progressively and selectively replaced if a complete rebuild is not undertaken.

8 Emerging Constraints

The key service constraints and monetised risk identified for the aging and deteriorated assets at WMTS are described in this section.

8.1 Safety and Environmental Hazards

8.1.1 Transformers

As described in AMS 10-67 Power Transformers and Oil Filled Reactors, Transformers B1, B2 and B3 at WMTS have synthetic resin bonded paper (SRBP) 220 kV bushings. These bushings are of an obsolete design. Condition assessments indicate de-lamination of the SRBP core in several bushings on these transformers resulting in oil draining from the bushing into the transformer main tank. Rigorous monitoring of oil levels to close tolerances and frequent transformer outages are required to maintain oil conservator levels and to replace the oil lost from the bushings to prevent the ingress of moisture and subsequent bushing failure.

The failure of a transformer bushing could cause a fire and some of these type of failures have resulted in the complete destruction of the transformer plus damage to other equipment. AusNet Services' network experienced 220 kV bushing failures and transformer fires in 1965 and 1987 at Dederang Terminal Station from this failure mechanism. Four recent interstate bushing failures in Queensland and New South have involved complete transformer failures. These failure modes present a safety risk to personnel working in the vicinity of the transformer due to the nature of the failure which could sometimes result in projectiles or oil fires.

AusNet Services has initiated two refurbishment projects X417[9] (Stage 1) and Project X834[10] (Stage 2) to replace this type of bushing on transformers where other key transformer components including the 'core and coils' are in sound condition and additional transformer service life is probable. The poor core and coil condition of the WMTS transformers suggests that bushing replacement is not economic.

8.1.2 Circuit Breakers

Most of the 66 kV circuit breakers at WMTS are bulk oil technology circuit breakers. As described in AMS 10-54 Circuit Breakers, bulk-oil circuit breakers have proven expensive to maintain in comparison with more modern technologies. In addition, explosive failures of bulk oil circuit breakers have occurred in the past, resulting in plant damage and fire ignition.

Due to the large volume of insulating oil within the tanks and the high voltage bushings, failures could potentially cause collateral damage to adjacent high voltage plant, cables, secondary systems and onsite personnel. Spillage of oil also poses environmental hazards and clean-up costs as bulk oil circuit breakers are not positioned within a bunded area.

8.1.3 Current Transformers

As described in AMS 10-64 Instrument Transformers, several explosive failures[11] have confirmed that deteriorated single-phase, porcelain clad, oil insulated current transformers present an unacceptable risk. This risk includes supply outages, collateral plant damage, environment damage and possible injury to personnel. A progressive replacement with toroidal current transformers incorporated within plant such as dead tank circuit breakers is part of AusNet Services' asset management strategy to address these risks.

9 X417 220 kV Transformer Bushing Replacement – Stage 1 at Ballarat Terminal Station, Ringwood Terminal Station and West Melbourne Terminal Station, completed in 2007.

10 X837 220 kV Transformer Bushing Replacement – Stage 2 at West Melbourne Terminal Station, Richmond Terminal Station, Ballarat Terminal Station, Geelong Terminal Station, Shepparton Terminal Station and Morwell Power Station, target completion in 2014.

11 Moorabool Terminal Station 2002 & 2005, Jeeralang Terminal Station 2003, Ballarat Terminal Station 2006 and Terang Terminal Station 2006.

8.2 Safety, Plant Collateral Damage and Environmental Risk Cost

The Electricity Safety Act requires AusNet Services to design, construct, operate, maintain and decommission its supply network to minimize hazards and risks, so far as is practicable, to the safety of any person arising from the supply network.

In practice this means safety risk should be proactively managed until the cost becomes disproportionate to the benefits. With respect to the management of safety risks that may cause a single fatality amongst a crew of workers; application of the principle of "as low as reasonably practicable" indicates costs in excess of $ [C-I-C] may be disproportionate.

The following assumptions were used to calculate the monetise safety, plant collateral damage and environmental hazards presented by the plant described in Section 8.1; consistent with the methodology described in AMS 10-24 Victorian Electricity Transmission Network – Asset Renewal Planning Guideline:

- An explosive failure or oil fire could injure or kill workers on site with an economic consequence cost of $ [C-I-C];
- Plant that contains large volumes of oil poses an environmental risk with an average consequence cost of $30k per event;
- Transformer with oil that contains poly-chlorinated biphenyls (PCB) poses an environmental risk with an average consequence cost of $100k per event;
- Plant collateral damage, including consequent supply outages, is on average $1.0 Million per event.

The likelihood of the above hazards occurring at WMTS have been calculated from the major failure rates in the circuit breaker, current transformer and power transformer reliability centred maintenance (RCM) models and the CIGRE research into the probability of explosion and fire associated with major plant failures[12].

Figure 6 shows the expected safety, plant collateral damage and environmental risk cost at WMTS based on the following risks:

- Health and safety risk due to an instrument transformer or bulk oil circuit breaker explosive failure;
- Environmental risk presented by insulating oil spillage;
- Collateral damage to adjacent plant due to catastrophic failure of bulk oil circuit breakers or instrument transformers.

[12] Cigre Final Report of the 2004 – 2007 International Enquiry on Reliability of High Voltage Equipment.

[C-I-C]

Figure 6 – Expected Annual Safety, Plant Collateral Damage and Environmental Risk Cost

8.3 Reliability and Security of Supply Risk

8.3.1 220 kV Switchyard

The 220 kV switching configuration is non-standard with most circuits connected with only one circuit breaker to a single bus. This is different to the standard breaker and half or double bus switching configurations normally used for transmission voltages of 220 kV or higher. A major failure of some of the 220 kV circuit breakers could result in multiple transformer outages, potentially impacting on the load supplied from WMTS.

8.3.2 66 kV Switchyard

Most of the 66 kV circuit breakers at WMTS are bulk oil technology circuit breakers and the consequence of a circuit breaker failure include:

- A fault on any of the transformer circuit breakers will result in an outage of a transformer.
- A fault on any of the bus-tie circuit breakers could cause a short outage of two buses. All circuits may be restored after isolating the faulty circuit breaker. The result of such an event is that potentially tens of thousands of customers will experience a power outage for at least 60 minutes.
- A fault on any of the feeder circuit breakers could cause a short outage of a bus which can only be restored once the faulty circuit breaker is isolated. The result of such an event is that potentially tens of thousands of customers will experience a power outage for at least 60 minutes.

8.3.3 Expected Supply Risk

Figure 7 shows the expected supply risk cost associated with 220 kV, 66 kV and 22 kV switchgear failures, secondary asset failures as well as 220/66 kV transformer failures (N-1, N-2 and N-3) at WMTS.

Figure 7 – Expected Supply Risk Cost for switchgear, secondary asset or transformer failures

8.4 Baseline Risk

The baseline risk for WMTS is illustrated in Figure 8. The monetised baseline risk includes safety, environmental, collateral plant damage and security of supply risks involved with both major transformer failures resulting in extended transformer outages and initial plant failures. It presents the probability weighted risk at WMTS for the key risk components as calculated in the preceding sections 8.2 and 8.3[13].

[C-I-C]

Figure 8 – Baseline Risk

The baseline risk in Figure 8 is the probability weighted risk cost at WMTS of low probability, but high consequence events. It does not represent the actual societal cost of a fatality or injury, or loss of supply event.

13 The initial reduction in risk is as a result of planned load transfers to BTS and the retirement of the 22 kV assets at WMTS.

The societal cost of explosive plant failures that could injure or kill workers on site and/or critical plant outages that could result in a loss of supply from WMTS are much higher than the probability weighted monetised risk presented in Figure 8. It is estimated at $ [C-I-C] for a fatality, $4.1 M for a major transformer failure, and $6.4 M for a circuit breaker or current transformer failure. The high societal cost of plant failures, including explosive failures, suggests that options such as "Do nothing" or "Run to Failure" are not prudent asset management strategies for the asset failure risks at WMTS.

The safety and asset failure risk is forecast to progressively increase over time, predominantly due to the deteriorating condition of the transformers and switchgear. The societal cost due to plant failures at WMTS is also expected to increase as demand increases. Table 7 illustrates that significant capital investments may be economic to address the increasing base line risk at WMTS.

YEAR	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25
Annual Risk Cost ($)	9.2	8.2	7.4	6.9	7.7	8.3	8.7	9.5	10.5	11.6
Present Value Risk Cost at 7.5% Discount Rate ($M)	117.8	104.7	94.5	89.0	98.5	106.5	111.9	122.3	134.4	148.7

Table 7 – Societal Risk

9 Options to Address Risks

The following options have been assessed to address the increasing community risk at WMTS:

- The Business as usual option is included in the option analysis to define the baseline risk and to quantify the potential benefits for options that address these risks;
- Non network option of embedded generation and/or demand side response;
- Run to failure and replace assets upon failure;
- Redevelopment with Air Insulated Switchgear (AIS);
- Redevelopment with Gas Insulated Switchgear (GIS);

10 Evaluation of Options

An economic cost-benefit assessment is used to assess and rank the economic efficiency of the non-network and network options listed in Section 9. The option analysis considers key aspects like operating cost versus capital cost trade-offs, security of supply risk during the construction phase of the project, economic merits of an integrated versus staged replacement and the future augmentation plans for WMTS.

A "Business as usual" option (Option 1) has been included in the option analysis to present the baseline risk. It illustrates whether deferment of asset replacement presents an economical option or whether the risk has reached a level that needs to be addressed during the 2017 to 2022 regulatory control period. Option 2 assesses the technical and economic merits of non-network options such as embedded generation and demand side management. Option 3 is a reactive asset replacement option. Options 4 and 5 involve proactive replacement of deteriorated and failure prone equipment based on the assessed risk of an asset failure.

The economic analysis allows comparison of the economic cost and benefits of each option to rank the options and to determine the economic timing of the preferred option. It quantifies the capital, operation and maintenance, and risk cost for each option. The risk cost includes safety, security of supply, environmental and collateral damage risks at WMTS. The robustness of the economic evaluation is tested for three discount rates, a sensitivity analysis of the forecast plant failure rates, different demand growth scenarios and different VCR rates.

Each of the identified options for WMTS is evaluated based on the incremental benefits it delivers in the following areas:

- 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.

10.1 Option 1: Business as usual

The baseline risk at WMTS, as shown in Figure 8 and Table 7, defines the economic cost for the "Do Nothing" option for the period until 2024. It shows that the annual risk cost increases from $9.2 M to $11.6 M over the period from 2015 to 2024. The Present Value of the risk cost, assuming a flat risk profile after 2024, is more than $148.7 M[14]. This suggests that a "Do Nothing" approach would not be an economical option or a prudent management strategy for the assets at WMTS.

The progressive reduction in reliability of supply and increase in safety risk is inconsistent with AusNet Services' obligations under the National Electricity Rules. Recurring asset failures is furthermore inconsistent with the

14 This is a conservative assumption as the risk cost is more likely to increase as a result of deteriorating plant condition and consequent failure rates, and demand growth.

requirements of the Electricity Safety Act and AusNet Services' accepted Electricity Safety Management Scheme.

This option is used in the economic evaluation as a reference to measure the economic benefits of options that mitigate the identified risks at WMTS and to ascertain the economical time[15] for a particular option to proceed.

10.2 Option 2: Non network options of embedded generation and/or demand side response

WMTS does not have any N-1 energy at risk under 50% POE conditions based on the current demand forecast for the planning period from 2015 to 2024 and only a very small amount of energy at risk on extremely warm days and summer 10% POE conditions at the end of the planning period. The economic benefits of non-network options are hence limited over the planning period and insufficient to warrant further analysis of this option based on typical costs for non-network options. Non network options cannot address the safety risk or meet the full supply requirements at WMTS.

10.3 Option 3: Run to failure

This option involves replacing assets upon failure, which poses a significant risk to the community. The community costs that would result from applying an asset management strategy to only replace an asset after the asset has failed is as follows:

- $4.1 M for a major failure of a 220/66 kV transformer.
- $6.4 M for a circuit breaker failure.

Some of the plant (bulk oil 66 kV circuit breakers and instrument transformers) at WMTS also present a safety risk should they fail explosively. This risk cannot be managed with a "run to failure" strategy as it would involve workers replacing failed equipment in a switchyard containing other equipment known to be in a deteriorated condition with a potentially hazardous mode of failure. This type of safety risk is valued at $ [C-I-C] as a person/s could be injured or killed following an explosive failure.

Unplanned replacement of assets after a failure occurred is furthermore an inefficient asset replacement strategy for terminal stations due to the significant higher cost (project mobilisation and demobilisation) of emergency replacements.

Recurring unplanned outages associated with a series of asset failures is inconsistent with the requirements of the Electricity Safety Act, AusNet Services' accepted Electricity Safety Management Scheme and the National Electricity Rules. This option is hence only used for modelling purposes.

10.4 Option 4: AIS Replacement

This option involves a like for like replacement of the 220 kV and 66 kV assets with AIS except for the existing 66 kV GIS bus that will be replaced with GIS. The four 150 MVA 220/66 kV transformers are replaced with three 225 MVA 220/66 kV transformers and the B4 transformer, which is still in a good condition, will be used elsewhere on the network. This option will retire all 22 kV assets at WMTS, including the 22 kV switchroom, 220/22 kV transformers and 22 kV fault limiting reactors.

This option delivers significant benefits and addresses all of the identified risks at WMTS.

10.5 Option 5: GIS Replacement

This option involves a replacement of the 220 kV and 66 kV assets with GIS. The four 150 MVA 220/66 kV transformers are replaced with three 225 MVA 220/66 kV transformers and the B4 transformer, which is still in a good condition, will be used elsewhere on the network. This option will retire all 22 kV assets at WMTS, including the 22 kV switchroom, 220/22 kV transformers and 22 kV fault limiting reactors.

15 "Do Nothing" is the default option until the year when the annual benefits (reduction in risk cost and operating cost) of the most economical option exceed the annual cost.

This option has the highest cost, but delivers significant benefits and addresses all of the identified risks at WMTS.

10.6 PV Analysis

The present value cost (taking into account the total project capital cost, supply risk cost, operation and maintenance cost, safety risk cost, environment cost and plant collateral damage risk costs) is calculated for all credible options and is summarised in Table 8. This allows for the options to be ranked based on their economic merits. A real discount rate of 7.5% is used for the base case.

Options Title	Assessment of Options	Capital Cost[16]	PV Cost (7.5% DCR)[17]
1. Business as usual	The baseline risk rises quickly, suggesting that a "Business as usual" approach is not sustainable.		More than $170 M
2. Non-Network Option	The low levels of energy at risk suggest that this option is uneconomic.		Uneconomic
3. Run to failure	This option is inconsistent with AusNet Services' accepted ESMS, the Electricity Safety Act and AusNet Services' obligations under the NER.		
4. AIS Replacement	Address all the identified risks in a single efficient project.	$118.8 M	$115.6 M
5. GIS Replacement	Addresses most of the risks.	$170 M	$140.6 M

Table 8 – Economic Assessment of Options – Base case assumptions

16 Total project cost expressed in real 2015 dollars and includes project overheads and finance charges.

17 Present value cost expressed in real 2015 dollars at a 7.5% discount rate.

The robustness of the economic assessment is tested for different discount rates[18], VCR rates (low case at 0.75 x base case and high case at 1.25 x base case), asset failure rates (low case at 0.75 x base case failure rate and high case at 1.25 x base case failure rate) and demand growth rates (plus and minus 15% of the base case forecast) as shown in Table 9 below.

	Discount Rate		
	6.0%	7.5%	9.0%
Option 1: Business as Usual	$190.665	$169.728	$151.591
Option 4: AIS Replacement	$125.254	$115.557	$106.819
Option 5: GIS Replacement	$152.988	$140.595	$129.451
Economic Option	Option 4	Option 4	Option 4

	VCR Rate		
	Low	Base	High
Option 1: Business as Usual	$148.192	$169.728	$191.265
Option 4: AIS Replacement	$110.005	$115.557	$121.109
Option 5: GIS Replacement	$135.872	$140.595	$145.318
Economic Option	Option 4	Option 4	Option 4

	Asset Failure Rate		
	Low	Base	High
Option 1: Business as Usual	$126.788	$169.728	$219.050
Option 4: AIS Replacement	$105.258	$115.557	$126.858
Option 5: GIS Replacement	$132.518	$140.595	$149.045
Economic Option	Option 4	Option 4	Option 4

	Demand Growth		
	Low	Base	High
Option 1: Business as Usual	$142.059	$169.728	$243.257
Option 4: AIS Replacement	$109.125	$115.557	$128.169
Option 5: GIS Replacement	$135.297	$140.595	$151.820
Economic Option	Option 4	Option 4	Option 4

Table 9 – Economic Assessment of Options – Sensitivity Study

10.7 Economic Option

The AIS replacement option (Option 4) is the most economic option to address the plant failure risks at WMTS as it has the lowest PV cost for all the scenarios shown in Table 9.

The PV for Option 4 is also calculated for a series of different years to determine the economical timing for it to proceed, consistent with the RIT-D guidelines. This assessment concludes that the economic timing for project completion is 2021.

Project Economic Timing (PV Cost $M)	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Project PV Cost	116.64	115.33	114.53	114.11	113.91	114.11	114.69

Table 10 – Economic Timing

18 AER Regulatory Investment Test for Transmission, June 2010. The present value calculations must use a commercial discount rate appropriate for the analysis of a private enterprise investment in the electricity sector. The discount rate used must be consistent with the cash flows being discounted. The lower boundary should be the regulated cost of capital, which is estimated at 6% (real and pre-tax).

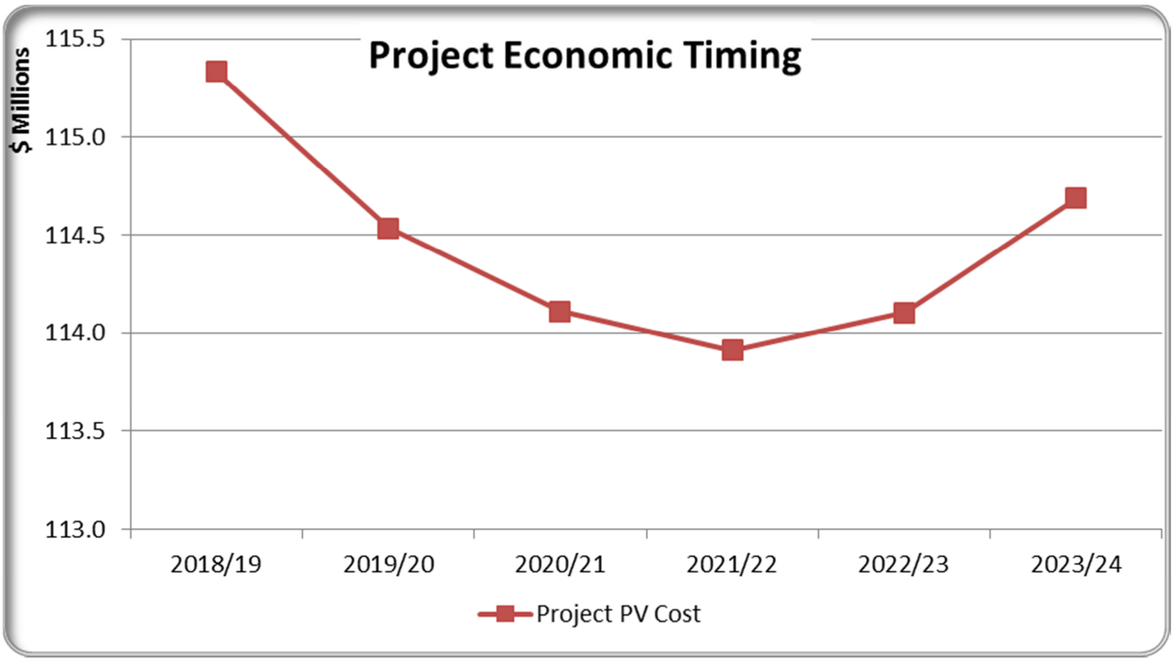

Figure 9: Project Economic Timing

10.8 Sensitivity Studies – Economical timing of preferred option

A sensitivity study[19] for higher (x 1.25) and lower (x 0.75) failure rates shows the economic timing may be as early as 2017 or as late as 2024. Due consideration of this sensitivity is important to avoid asset failure during the construction phase of the planned replacement project given the significant worker safety and community consequence.

19 The intersection of the annualized project cost plot and the incremental benefits plot shows the project timing that delivers the optimum economic outcome. The initial reduction in project benefits is a result of planned load transfers from WMTS to BTS and the retirement of the 22 kV assets at WMTS.

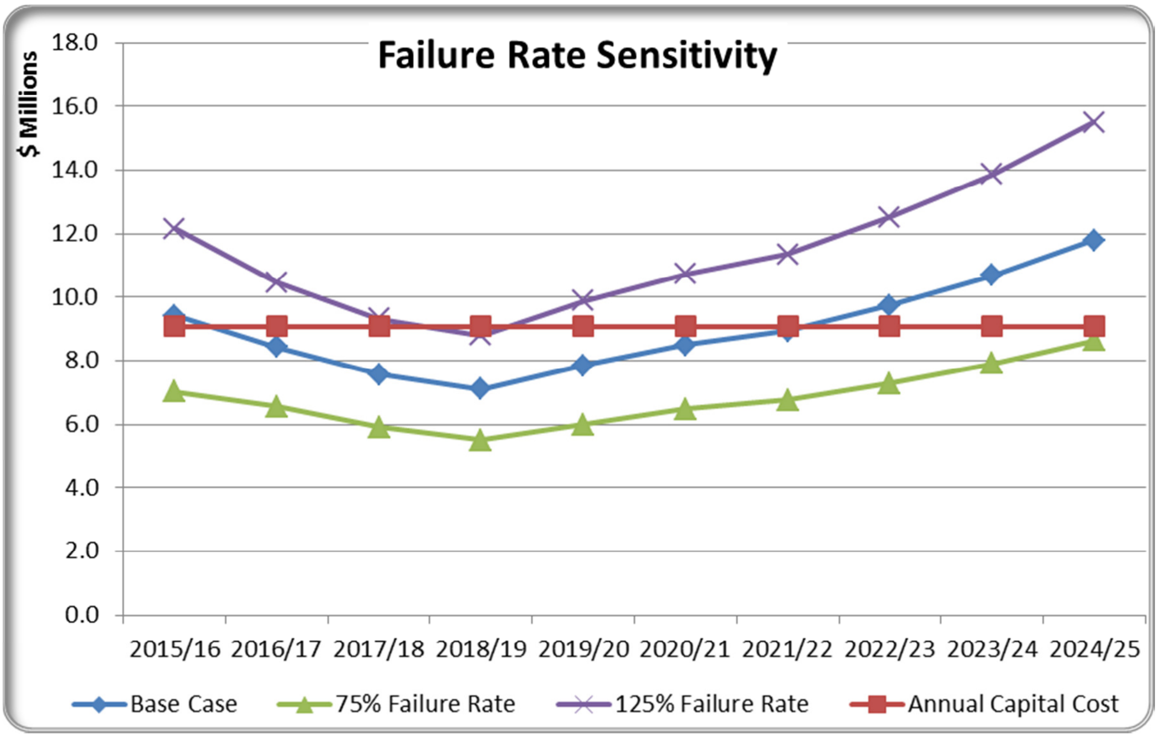

Figure 10 – Sensitivity Study – Plant failure rate higher or lower than expected

A sensitivity study for higher demand growth rates (15% above the base case) and lower demand growth rates (15% below the base case) shows that the project economic timing may be as early as 2019 or as late as 2023. Due consideration of this sensitivity is important to avoid un-necessary risk during the planned replacement project given the significant safety and community consequence.

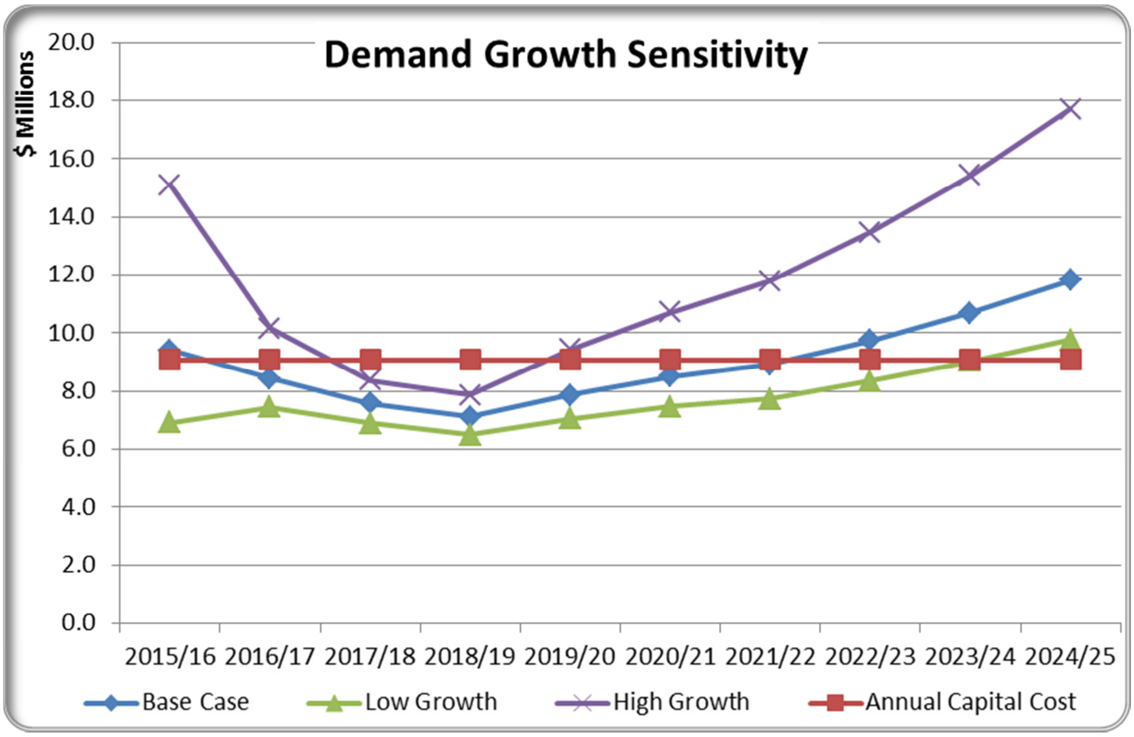

Figure 11 – Sensitivity Study – Demand growth higher or lower than expected

Note: Incremental benefits for option 7 under base case, high growth and low growth are overlapping in the graph above

The economical timing of the TSTS redevelopment is also tested for different VCR rates (25% higher or lower than the base case) as shown in Figure 12. The sensitivity study shows that the project economic timing may be as early as 2019 or as late as 2023. Due consideration of this sensitivity is important to avoid un-necessary risk during the planned replacement project given the significant safety and community consequence.

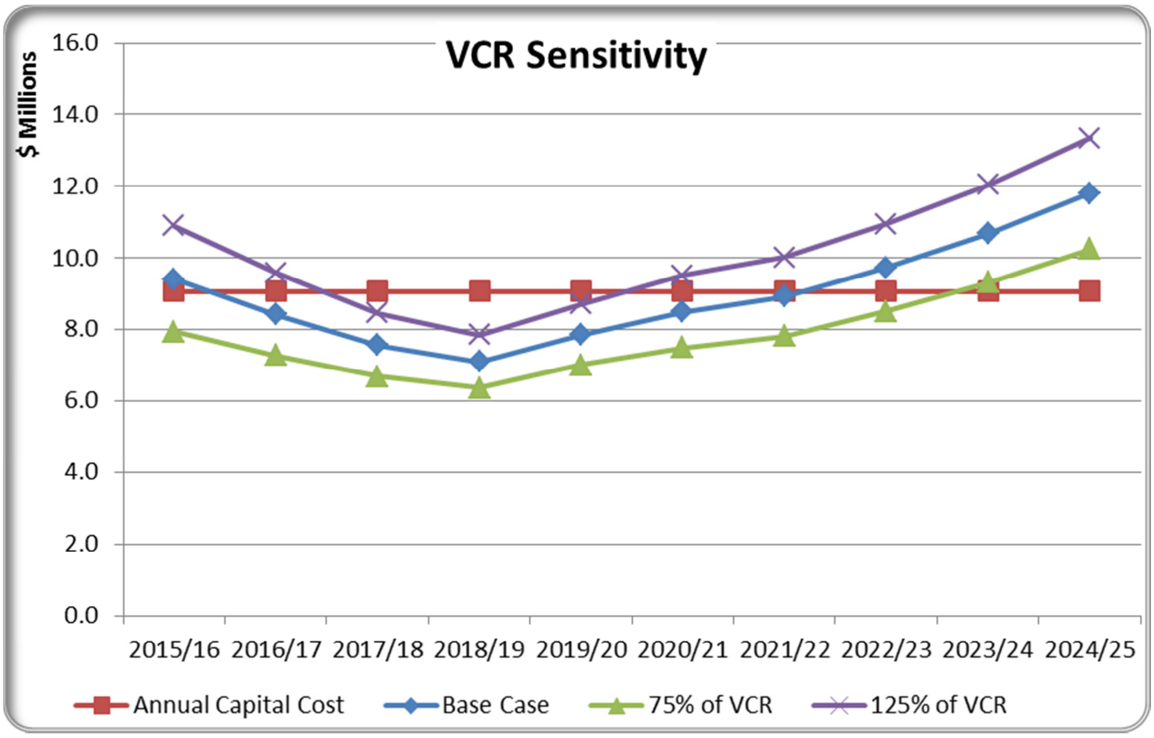

Figure 12 – Sensitivity Study – VCR Rates higher or lower than expected

Operational measures such as additional plant inspections and condition monitoring to manage the safety risk until planned replacements are completed is economical based on the safety risk assessment in Section 8.2.

11 Scope of Work

The high level scope of work for the preferred solution (Option 4) includes:

- Like for like replacement of the 220 kV switchgear with AIS
- Like for like replacement of the 66 kV switchgear with three AIS buses and one GIS bus
- Replacement of the 150 MVA 220/66 kV transformers with three 225 MVA 220/66 kV transformers. The B4 transformer, which is still in a good condition, will be used elsewhere on the network.
- Replacement of protection and control systems in a new control building
- Retirement of the 22 kV assets, including two165 MVA 220/22 kV transformers, 22 kV switchroom and 22 kV fault limiting reactors

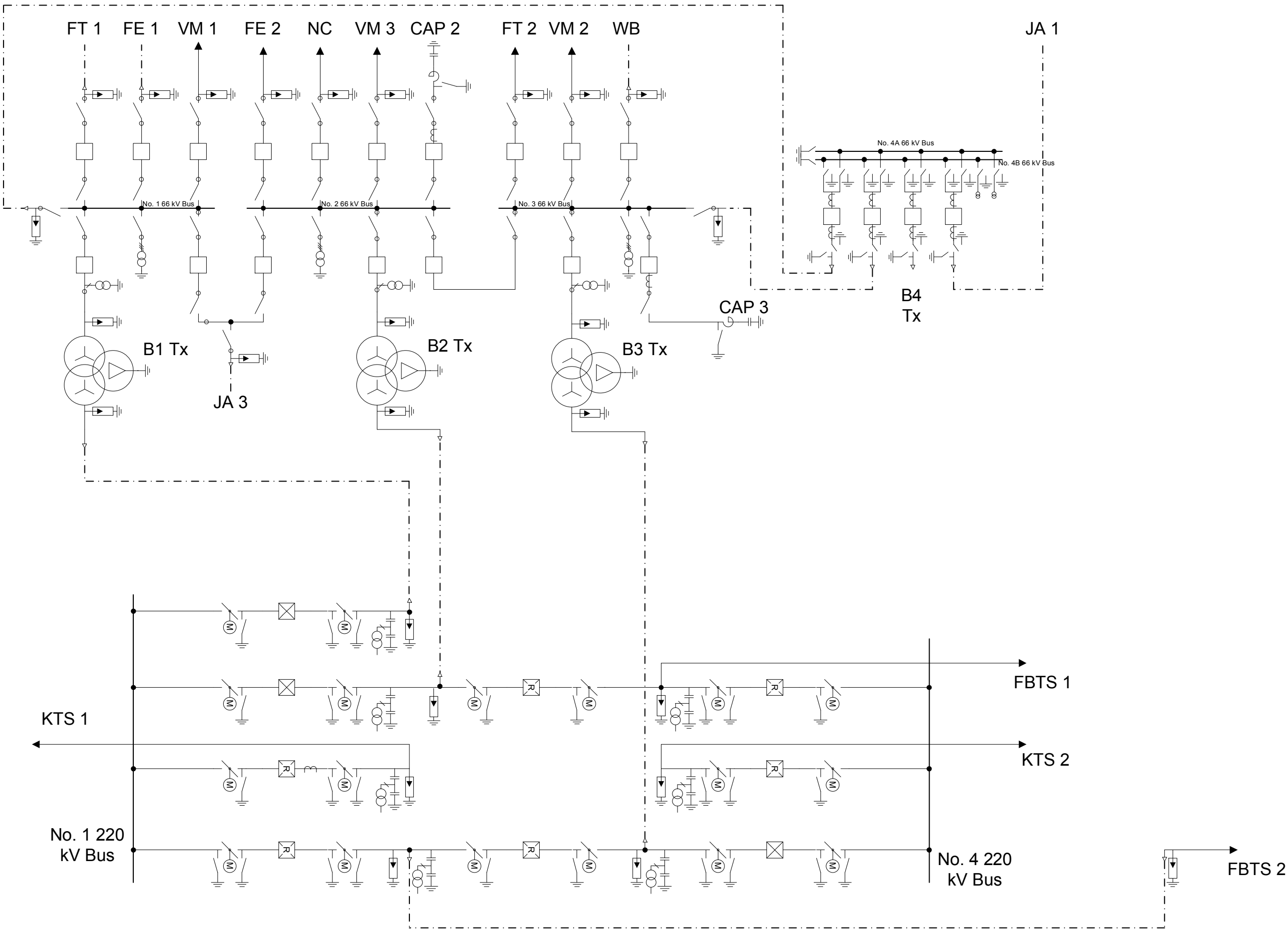

Figure 13: Proposed works at WMTS

APPENDIX A: PLANNING ESTIMATE FOR PREFERRED OPTION – OPTION 4 – AIS REPLACEMENT

[C-I-C]

Note: The costs in the table above are expressed in 2015 real dollars.