MAJOR AUGMENTATION PROPOSAL

OPTIONS PAPER

Perth CBD: Hay/Milligan Supply Reinforcement Investment

Date:
7 July 2017

Prepared by:
Network Planning
Western Power
GPO Box L921, Perth WA 6842
ABN 18 540 492 861

DOCUMENT PURPOSE

For the benefit of those not familiar with the Electricity Networks Access Code 2004, Western Power offers the following clarifications on the purpose and intent of this document:

1. Western Power as a prudent electricity networks business is required to carry out forward planning to identify future reliability of supply requirements and to issue this type of document for proposed "Major Augmentations" to the covered network.
2. The Electricity Networks Access Code 2004 requires that Western Power should properly assess each Major Augmentation to determine whether it maximises the "Net Benefit" to those who generate, transport or consume electricity after considering alternative options.
3. This document contains the results of this assessment and a draft recommended solution to address future supply requirements from March 2020. Interested parties are invited to comment on the draft recommendation.

What the document does NOT mean:

A. It does NOT mean that the electricity supply interruptions are imminent. The identified supply interruption scenario is a high consequence event with low likelihood, which has not been observed in the system during the past 10 years, with its likelihood expected to increase from 2022. There is sufficient time to implement a solution with mitigation strategies in place to prevent any associated supply interruptions.

B. It does NOT mean that Western Power has been surprised. It is, in fact, part of the standard Western Power planning processes.

Contents

Glossary

The list of abbreviations and acronyms used throughout this document is shown in Table 1.

Table 1: List of Abbreviations and Acronyms

Abbreviation / Acronym	Definition
AIS	Air Insulated Switchgear
CBD	Central Business District
CK	Cook Street
DSM	Demand Side Management
DTC	Distribution Transfer Capacity
EP	East Perth
ERA	Economic Regulation Authority
F	Forrest Avenue
GIS	Gas Insulated Switchgear
HAY	Hay Street
HV	High Voltage
IEM	Investment Evaluation Model
JTE	Joel Terrace (132 kV)
LV	Low Voltage
MIL	Milligan Street
MLA	Mount Lawley
MVA	Mega Volt Amperes
NDP	Network Development Plan
NP	North Perth
NPC	Net Present Cost
PTA	Public Transport Authority
RMU	Ring Main Unit
SUM	Summers Street
W	Wellington
WACC	Weighted Average Cost of Capital

Executive Summary

Introduction

The East Perth (EP) and CBD load area experienced significant growth in the last 25 years and electricity infrastructure developed progressively to meet the electricity demand. There are several assets that have deteriorated during this period and require remediation, replacement or treatment resulting in the need for investment to ensure that customers in this load area, particularly the Perth CBD boundary (as defined under the Technical Rules), continue to benefit from a secure and reliable electricity supply.

In addition, the substations within the Perth CBD boundary are designed to operate under the Perth CBD Criterion as per Technical Rules clause 2.5.3 which requires Western Power to have sufficient power transfer capacity in the transmission system to maintain supply to all customers following an outage of any two transmission elements. Hay Street (HAY) and Milligan Street (MIL) substations were non-compliant (albeit marginally) with the Perth CBD Criterion in 2015 for which Western Power has discussed a Technical Rules exemption request with the Economic Regulation Authority (ERA) whilst it identifies a prudent and efficient compliant solution.

Western Power recognises the importance of reliable and secure electricity supply to customers and has completed planning investigations to identify the most prudent and efficient course of action to continue to meet the needs of its customers in the EP and CBD load areas.

This document outlines the options considered by Western Power to address the deteriorated condition of assets in the EP and CBD load areas, the treatment of which will also achieve compliance with the Perth CBD Criterion and provide a capacity benefit to the Perth CBD boundary (in particular for Forrest Avenue (F) and Wellington (W) substations). The key selection criteria for options are to:

- address the condition of assets in the most optimal and cost effective manner
- meet forecast demand for the foreseeable future
- adhere to CBD compliance obligations which are consistent with (albeit less stringent than) other Australian capital cities.

This Options Paper proposes a series of network investments within the development strategies for the EP and CBD load area, one of which involves the construction of a new 132 kV transmission cable between HAY and MIL substations. Western Power believes that this solution is the preferred investment pathway to resolve the aforementioned drivers, achieve compliance with Perth CBD Criterion and maximise the net benefit to those who generate, transport or consume electricity.

Western Power has prepared this Options Paper, in accordance with the requirements of chapter 9 of the Electricity Networks Access Code 2004, for public consultation as part of the Regulatory Test process for a Major Augmentation Proposal to the Western Power network. The objective of the Options Paper is to inform the public, in general, and interested parties, in particular, of the Major Augmentation Proposal and to obtain input with regard to any additional or alternative considerations. Key stakeholders are encouraged to submit opinions and to offer alternative solutions to the ones proposed by Western Power. A summary of the outcomes of the public consultation and submissions will be published as part of Western Power's submission to the ERA for a Major Augmentation Proposal and associated Regulatory Test requirements.

The main elements of the Major Augmentation Proposal covered by this Options Paper are as follows:

- The installation of a new 132 kV transmission cable between HAY and MIL substations
- The installation of associated equipment at HAY and MIL substations to enable the connection of the new cable
- Upgrade of assets at HAY, MIL and neighbouring substations to withstand the increased fault levels (that result following the installation of the proposed 132 kV transmission cable).

- Facilitates the decommissioning of F, W and EP 66 kV substations

Network Issues

The EP and CBD load area has assets that have deteriorated, requiring mitigation as soon as practicable, but at least within the next 5 years. This will be staged and driven by the severity of the asset conditions. Some of the critical assets that are required to be addressed within the 10 year planning horizon are:

- Switchboards at HAY, F and MIL substations
- Transformers at F and W substations
- Transmission cables between EP and W substations

Options Considered

The assessment of potential development strategies for the EP and CBD load area over a 25 year period gave specific consideration to the defined key selection criteria for the options.

Assessment of these investment drivers across the EP and CBD load area over the strategy period of 25 years led to the development of five discrete development strategies:

1. Development Strategy 1 – Like for like replacement
2. Development Strategy 2 – CBD substation
3. Development Strategy 3 – HAY-MIL 132 kV cable
4. Development Strategy 4 – Minor distribution upgrades and defer HAY-MIL 132 kV cable by two years
5. Development Strategy 5 – Major distribution upgrades

Non-network alternatives have not been considered as part of these strategies as the primary driver is aged and deteriorated assets, and non-network solutions are ineffective in resolving these types of issues.

In order to determine the most appropriate option to meet the key selection criteria, it is necessary to have regard to the long term impact of this decision as contrasted with offering a short term solution that might result in inefficient costs and/or stranded assets at the respective substations. Therefore, this paper assesses options across a 25 year period.

Evaluation

The five capital investment development strategies identified were evaluated against a range of financial and technical performance metrics, and the output of this analysis including asset rationalisation (as a primary objective) and capacity benefits obtained (inherent in the asset solution) is outlined in Table 2.

.

Table 2: Financial Assessment and Network Capacity Benefit

Strategy	Description	**Primary benefit – mitigate deteriorated assets,** *resulting in assets rationalised within load area as listed below*	NPC ($M)	**Additional benefit** *Approximate additional available capacity from 2023 onwards*	
				Distribution Feeder Capacity	**Transmission Substation Capacity**[1]
1	Like for Like Replacement	No change to the number of assets	$172.2	Nil	Nil
2	CBD Substation	Net reduction of one zone substation, and: • 4 x transformers • 2 x switchboards and • 2 x transmission lines	$244.6	70 MVA (shared across EP and CBD load area)	CBD: 70 MVA
3	HAY-MIL Cable	Net reduction of one terminal and two zone substations, and: • 6 x transformers • 4 x switchboards and • 3 x transmission lines	$128.2	81 MVA (shared across EP and CBD load area)	MIL: 70 MVA HAY: 35 MVA
4	Minor Distribution Upgrades and Defer HAY-MIL Cable by two years	Net reduction of one terminal and two zone substations, and: • 6 x transformers • 4 x switchboards and • 3 x transmission lines	$134.4	81 MVA (shared across EP and CBD load area)	MIL: 70 MVA HAY: 35 MVA
5	Major Distribution Upgrades	Net reduction of one terminal and two zone substations, and: • 6 x transformers • 4 x switchboards and • 4 x transmission lines	$144.0	31 MVA (shared across EP and CBD load area)	Nil

The results of this analysis identify Development Strategy 3 as the most efficient and appropriate long term solution for the EP and CBD load area which is recommended as it meets all required technical performance standards whist minimising the net present costs across the 25 year evaluation horizon.

Sensitivity analysis was undertaken to determine the impact of variations in cost (±20%) and load growth (±1%) to test the robustness of the recommended option. The output of the sensitivity analysis has demonstrated an outcome consistent with the base case economic analysis, in that Development Strategy 3 is still seen to have the lowest net present cost compared with the alternative options.

The first critical investment of this Development Strategy (and the subject of Western Power's Regulatory Test submission) is the installation of a 132 kV interconnecting transmission cable between HAY and MIL substations and associated works. This transmission cable will facilitate the eventual decommissioning of F and W substations in 2021 and 2023 respectively.

[1] Whilst the HAY-MIL transmission cable creates 70 MVA of capacity at each of HAY and MIL substations, a portion of the HAY capacity is utilised by the 35 MVA load transfer from F and W; the remaining 19 MVA load transfer from F to JTE has been excluded from these calculations, as the focus is capacity created within the Perth CBD and JTE is outside of that area. The transmission cable creates this capacity from the existing transformers at HAY and MIL by ensuring that the 132 kV transmission supply is maintained to both substations in the event of losing two transmission elements at either substation.

Conclusion

Based on the option analysis and having regard to Western Power's obligations under the Electricity Networks Access Code 2004 for Major Augmentations, it is recommended that the following investments be progressed:

By 2019:

- The installation of a new 132 kV transmission cable between HAY and MIL substations with the following specifications:
    - 1.95 km of 2000mm^2 copper conductor, XLPE insulated cable type to achieve 240 MVA summer rating
    - Proposed cable route as shown in Appendix A
- The installation of associated equipment at HAY and MIL substations to enable the connection of the new cable with AIS switchgear at HAY and GIS switchgear at MIL

By 2020:

- Mitigation of any under fault rated assets through the increased fault levels (due to the cable installation) at HAY, MIL and neighbouring substations.

The nominal capital cost of this option being $38.5 million (including project on costs and risk allowance) has been determined as part of the detailed cost estimate process through Western Power's Estimation and Value Assurance Section.

This solution is a key decision that sets the investment direction for the wider EP and CBD area to ensure that the asset age and condition issues, in particular, are addressed in a timely manner.

It should be noted that the draft recommended strategy for the EP and CBD load area is Strategy 3 and that the investments identified within it will be taken forward in due course. Some of these investments may be the subject of future Regulatory Tests.

1 Background

1.1 Geographical Area

1.1.1 East Perth and CBD Load Area

The East Perth (EP) and CBD load area encompasses the geographical boundaries of Perth CBD, the City of Subiaco and the City of Vincent. This load area features one terminal (EP Terminal) and seven zone substations that are owned and operated by Western Power whilst an eighth substation, Summers Street (SUM) provides a dedicated supply to the Public Transport Authority (PTA) and is not owned or operated by Western Power. Among the seven substations, Milligan Street (MIL) is supplied from Northern Terminal through Mount Lawley and James St substations, whilst the remaining substations are fed off EP Terminal. The current East Perth and CBD load area transmission network is depicted in Figure 1.

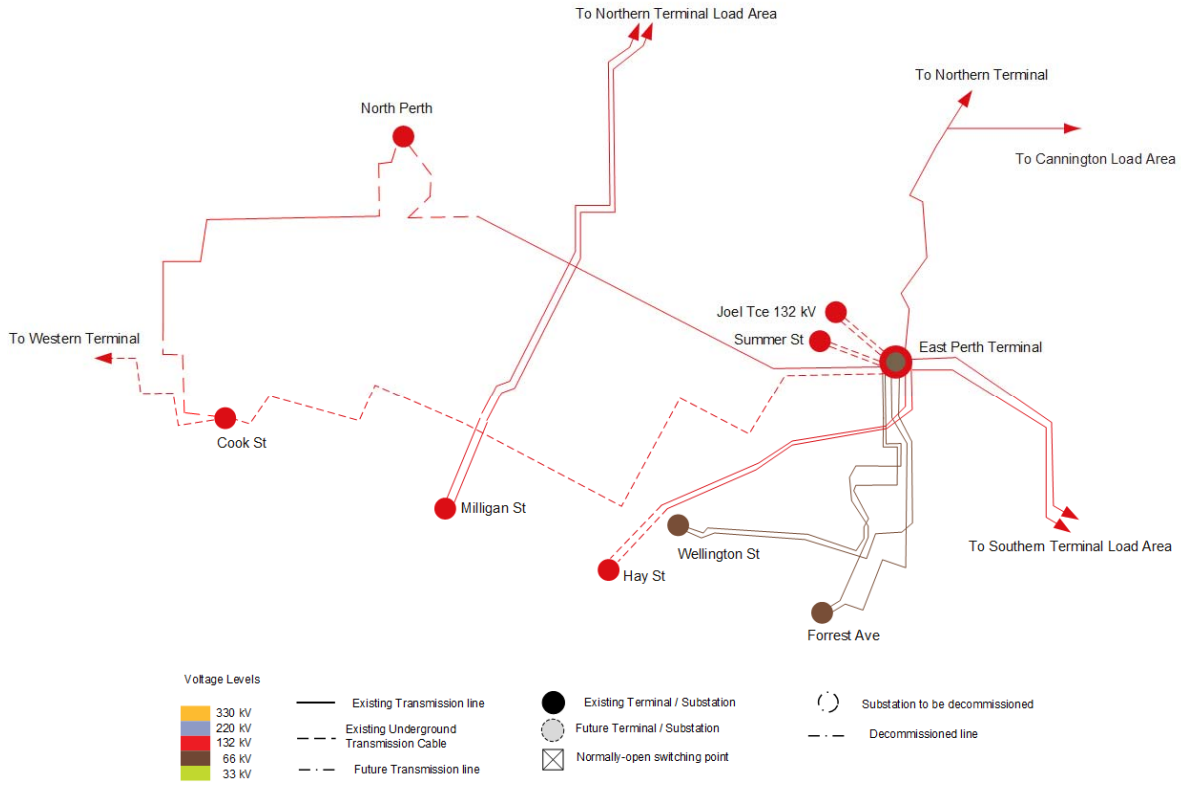

Figure 1: East Perth and CBD Load Area

1.1.2 CBD Boundary

Hay Street (HAY) and MIL substations are the two prominent Western Power 132/11 kV zone substations located within the defined Perth CBD area as per Technical Rules. The specific boundary associated with the Perth CBD supply area is denoted in Figure 2 via a blue dotted line. There are also several other substations, such as Cook St (CK), Wellington St (W) and Forrest Avenue (F) that are able to provide relevant support to maintain CBD consumer supplies via distribution system transfers and hence are designated to fall within the wider CBD outer boundary (shown in black).

Figure 2: Perth CBD Boundary and Key substations

1.2 East Perth and CBD Development Strategy and Network Development Plan

The EP and CBD development strategy takes into account the existing assets and network configuration within the EP and CBD load area and considers any proposed investments that are in the 10 year Network Development Plan (NDP). This approach will ensure that the network requirements in the 25 year period are well supported.

The EP and CBD development strategy was prepared in 2012 based on the Western Power 2011 load forecast[2], which envisioned high growth in this load area at the time. Due to the changing economic circumstances combined with low occupancy rates in this area, the high growth did not materialise and the 2016 load forecast illustrated marginal growth. Thus, the EP and CBD development strategy was updated in March 2017 based on the revised forecast, updated asset conditions and critical investment drivers.

The 2016 NDP details the network and non-network investment plans for augmentation and optimised replacement required to address the current and forecast transmission and distribution network limitations over the period 2017/18 to 2026/27.

Both the EP and CBD development strategy, updated in March 2017, and the 2016 NDP articulate a consistent investment plan which is shown in Table 3.

[2] This is referred to as 2011 load forecast (or year when load forecast is developed) from this point forward.

Table 3: Investment Plan for EP and CBD Load Area as per Development Strategy and Network Development Plan

Investment	Benefit and Driver	By When
Replacement of 11 kV switchboards MIL substation	Address degraded asset condition.	2017/18
Installation of a 132 kV cable between HAY and MIL substation	Increase maximum supportable demand in the Perth CBD under N-2 conditions based on high load growth forecast in 2011.	2018/19
Upgrade of under fault rated equipment at Summer Street and MIL substations	Mitigate fault level constraints.	2018/19
Installation of dynamic line rating and line reactors on Northern Terminal –Belmont/ East Perth 132 kV circuit	Mitigate pre-contingent thermal constraints on the Northern Terminal – Belmont/ East Perth 132 kV circuit.	2021/22
Replacement of 11 kV switchboards at HAY substation	Address degraded asset condition.	2021/22
Replacement of EP-HAY 81 & 82 cables	Address degraded asset condition.	2022/23 & 2024/25
Installation of a new 132/11 kV CBD zone substation	Address degraded asset condition at F and W substations. Resupply the F and W substations to the new 132 kV CBD zone substation	2023/24
Decommissioning of F substation	Address degraded asset condition.	2026/27
Decommissioning of W substation	Address degraded asset condition.	2026/27
Decommissioning of EP 66 kV switchyard	Address degraded asset condition.	2026/27

1.3 Developments in Load Forecast and Asset Condition

Perth experienced one of its wettest summers and below-average temperatures in summer of 2016-2017. The abnormal weather conditions coupled with low occupancy rates and more energy efficient buildings in the EP and CBD load area resulted in a drop in the electricity demand in this load area. The 2017 load forecast subsequently illustrated a much lower load forecast than the 2016 load forecast.

The significant shift in the load forecast trend, particularly across 2015 to 2017, required the investments proposed during this period to be reviewed based on their primary drivers, particularly for investments driven by the need to cater for increased load demand. These investments include the 132 kV cable between HAY and MIL substations and new 132/11 kV CBD substation.

The condition assessment of various assets in the EP and CBD load area have also been reassessed, now indicating a higher risk than previously contemplated. This reassessment was informed by an external audit reports that highlighted a higher consequence of failure of the deteriorated assets. This subsequently led to a reprioritisation of the investment pathway at F and W substations in order to resolve the known asset age and condition issues in an appropriate timeframe (and with consideration to deliver these works in a controlled and staged way).

2 Electricity Demand

2.1 Overview

The maximum forecast load demand referred to in this Options Paper is based on the Western Power, June 2017 release, load forecast with only firm network and customer investments included. The load forecasts for each site are based on a 10% Probability of Exceedance (PoE) which is consistent with the Western Power's Transmission Planning Guidelines. The load forecast is utilised to guide the triggers and staging of developments described within the strategies. It is noted that these triggers will vary year on year as more refined forecasts are provided, however the comparative assessment of a preferred solution will be largely unaffected.

Peak load diversity has been excluded from this assessment and it is assumed that all substations in the CBD will experience peak load conditions at approximately the same time. This is considered to be a fair assumption due to the load in the EP and CBD load area being primarily commercial with high density residential; as such load peaks will naturally occur at comparable times largely influenced by high ambient temperatures.

2.2 Load Forecast

2.2.1 HAY and MIL substations

HAY and MIL substations supplied a combined load of 144.7 MVA and 131.3 MVA during their peak demands in 2016 and 2017 respectively.[3] This is a material decline from 2013, when combined load supplied was 160.8 MVA.

The Western Power load forecast released from 2015 to 2017 depicts a downward trend for HAY and MIL substations on the basis of the decreasing actual demand during this period (with HAY 2016 actuals being an outlier). These are shown in Figure 3 and Figure 4.

The load demand for these two substations is driven by new large scale commercial and high density residential developments which are highly volatile and typically correspond to the economic and environmental conditions within the State. Moreover, developments in emerging technology (as detailed in Section 1.2) have made forecasting beyond the five year horizon much more challenging than in the past. Thus, despite the downward load trend at these substations per the 2017 load forecast, an upturn in the State economy could rapidly increase the future load demand and Western Power is obligated to provide for these changing trends.

[3] This excludes any load transfer that may have occurred during the respective peak demands.

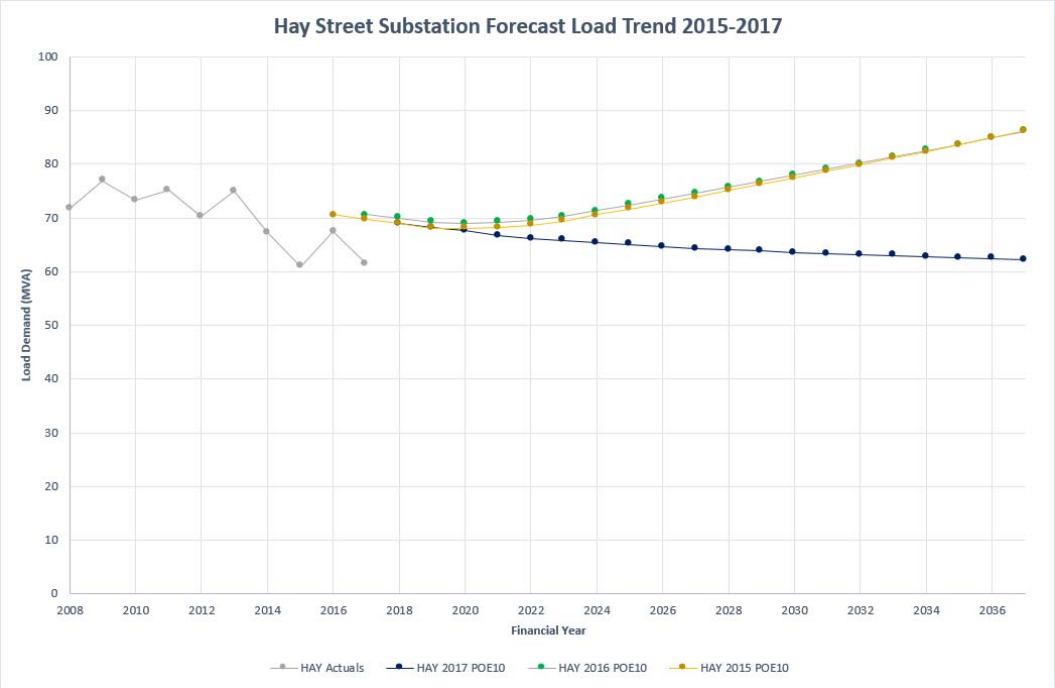

Figure 3: HAY Substation Forecast Load Trend 2015-2017

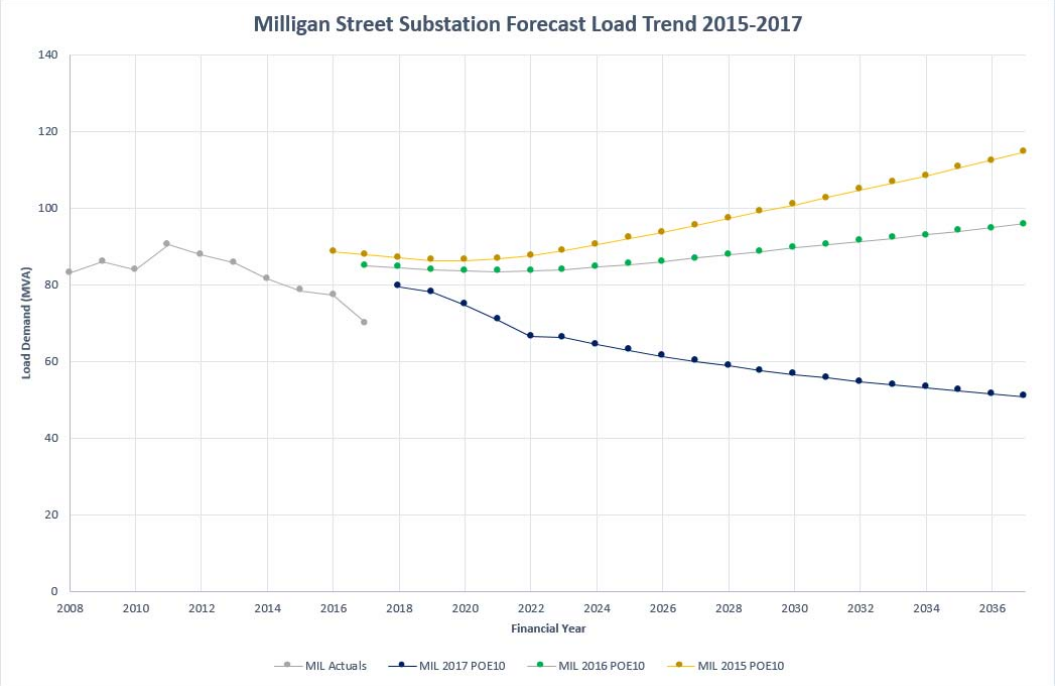

Figure 4: MIL Substation Forecast Load Trend 2015-2017

2.2.2 F and W substations

F and W substations have aged and deteriorated asset conditions for which the long term investment strategy is the decommissioning of the substations when technically and practically feasible (explained further in Section 3.2). Prior to the decommissioning, the loads connected to these substations are required to be offloaded to adjacent substations to maintain supply. The implications of this load transfer together with

suitable and efficient mitigation strategies are discussed in this Options Paper having regard to the 2017 load forecast shown in Figure 5 and Figure 6 for F and W substations respectively.

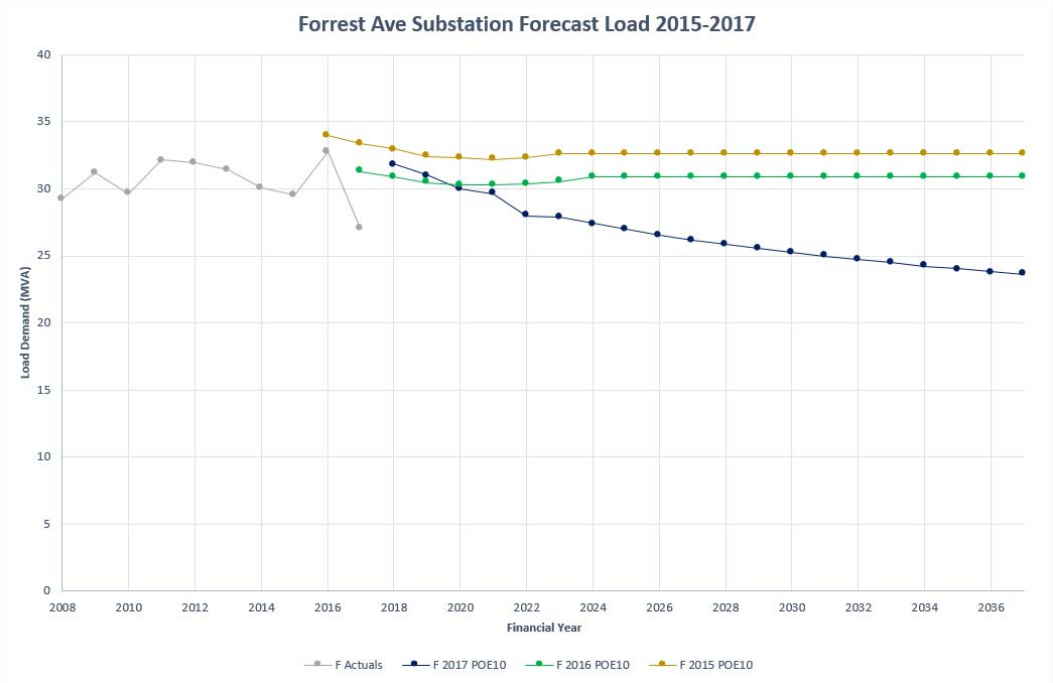

Figure 5: F Substation Forecast Load Trend 2015-2017

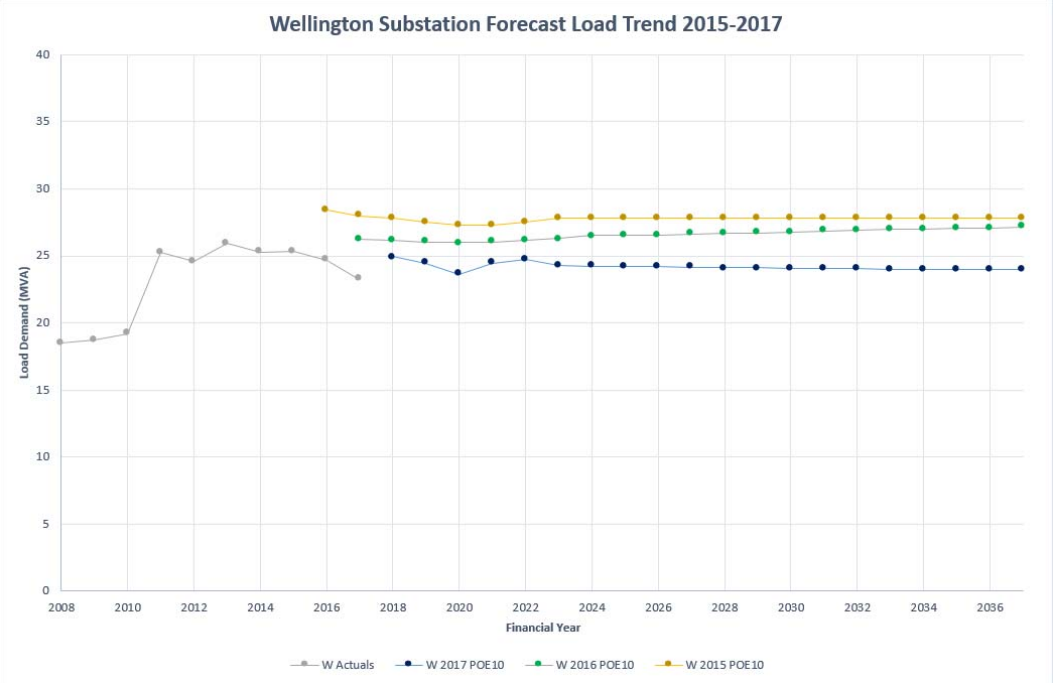

Figure 6: W Substation Forecast Load Trend 2015-2017

3 Planning Drivers and Asset Condition

3.1 Planning Criteria for Network Development

Western Power has security, reliability and quality of supply obligations defined in the Technical Rules (December 2016) and identified in Chapter 12 of the Electricity Networks Access Code 2004.

The Perth CBD boundary (as defined in the Technical Rules), predominantly supplied by HAY and MIL substations, is of high importance with sensitive financial and Government establishments interleaved with significant levels of commercial customers. The specific requirements under which Western Power plans and operates the electricity transmission system, supplying the designated Perth CBD boundary, are stated in the Technical Rules under clause 2.5.3 – Perth CBD criterion (N-2). This clause requires Western Power to have sufficient power transfer capacity in the transmission system to maintain supply to all customers following an outage of:

- One or two transmission lines (clause 2.5.3(b)(1))
- One or two supply transformers (clause 2.5.3(b)(2))
- One transmission line and one supply transformer (clause 2.5.3(b)(3))

These rules apply to new network upgrades or modifications; however, the operation of clause 1.9.4(a) of the Technical Rules effectively means that Western Power is deemed to be compliant if it adheres to the CBD reliability criteria[4] that predated the Technical Rules. These criteria allow the distribution and/or transmission networks to be used to achieve full restoration of supply within two hours in the event of either:

- Two unplanned contingencies
- One planned and one unplanned contingency

Western Power, makes use of available distribution transfer capacity (DTC) in the network to meet the two hour restoration requirement and identified Hay Street (HAY) and Milligan Street (MIL) substations to be non-compliant (albeit marginally) with the Perth CBD Criterion in 2015. Following this, Western Power has discussed a Technical Rules exemption request with the ERA whilst it identifies a prudent and efficient compliant solution.

Western Power continuously assesses the current and future capability of its network and takes action to ensure that it will continue to meet the required performance standards. As a part of these planning processes Western Power has identified that action is required to ensure that the network supplying the EP and CBD load area will be able to meet these obligations for forecast peaks demands by summer of 2019/20. Solutions to address the forecast requirements are therefore classified under 'Safety or Reliability' as referenced in 6.52 (b) iii of the Electricity Networks Access Code 2004.

3.2 Asset Condition in the East Perth and CBD Load Area

The EP and CBD load area experienced significant growth in the last 25 years and electricity infrastructure was expanded progressively to meet the electricity demand. The condition of the assets within this load area illustrates this with three relatively new substations (CK, North Perth (NP) and Joel Terrace (JTE)) operating at 132 kV and three aged substations (EP, F and W) still operating at 66 kV.

EP (66 kV), HAY, MIL, F and W substations have asset condition issues that need to be addressed in the next 10 years. As these substations supply critical infrastructure and establishments within the Perth CBD, they

[4] Western Power Transmission Planning Criteria

would require an investment plan to ensure coordination of replacement works and adequate risk mitigation strategies. The condition assessment at these substations is undertaken based on the following asset classes:

- Zone substation transformers
- Switchboards
- Wood poles and steel structures
- Transmission lines and cables
- Distribution cables

As CK, NP and JTE substations are relatively new and do not have any identified asset condition issues, they are excluded from the asset condition assessment in this Options Paper. There are also no proposed investments at these substations in the updated 2017 EP and CBD development strategy and 2016 NDP.

The details of the condition of all assets considered is shown in Appendix B in full, with the assets requiring mitigation during the 10 year horizon to 2027 summarised in the sections below.

3.2.1 Zone Substation Transformers

The zone substation transformers that may need to be addressed are:

- EP terminal 132/66 kV T3 and T5
- F substation 66/11 kV T1 and T2
- HAY substation 132/11/11 kV T1 and T3
- MIL substation 132/11/11 kV T1 and T3
- W substation 66/11 kV T1

The 66 kV transformers at EP terminal, F and W substations are expected to be retired eventually due to their condition and with the long term efficiency of operating a 132 kV network instead of rebuilding these assets at 66 kV. The 132/11/11 kV transformers at HAY and MIL are essential to cater for the current and future loads within the Perth CBD boundary and would need to be replaced with similar transformers when due for replacement.

3.2.2 Switchboards

The substation switchboards that need to be addressed having reached their expected end of life are:

- F substation switchboard 1 and 2
- HAY substation switchboard 1
- Milligan substation switchboard 1

An external audit report on the condition of the aged switchboards in Western Power identified the switchboards at F, HAY and MIL substations to be at high risk of failure, having reached their expected end of life. This report also assessed the condition of the switchboards at these substations and determined their priority level to stage the mitigation of the switchboard condition as they cannot all be mitigated simultaneously. Any works undertaken at these switchboards would require the loads supplied through them to be offloaded to adjacent substations and have contingency plans in place. Therefore, simultaneous mitigation of the at risk switchboards is not practical.

HAY substation switchboard has the highest priority and is proposed for replacement by 2019. F substation switchboard is the next substation to be mitigated and as the internal options assessment determined that

decommissioning is the preferred solution, distribution upgrades are proposed to transfer the loads to adjacent substations by 2020. Thereafter, MIL substation switchboard is proposed for replacement by 2021.

The practical sequence of switchboard mitigation in the EP and CBD load area will alter the investment pathway proposed in the 2017 EP and CBD development strategy and 2016 NDP.

3.2.3 Transmission Wood Poles and Steel Structures

The expected life of transmission wood poles and steel structures is 40 and 50 years respectively. The assets that exceeded their expected end of life are:

- EP-F 71 66 kV line (4 wood poles and 2 steel structures)
- EP-F 72 66 kV line (9 wood poles and 2 steel structures)
- MLA-MIL 81 132 kV line (4 wood poles)
- MLA-MIL 82 132 kV line (2 wood poles)

The 132 kV line structures are expected to be replaced with like for like replacement or reinforced in the future. The 66 kV line structures are expected to be decommissioned once the other 66 kV assets at EP, W and F have been retired.

3.2.4 Transmission Lines

The transmission cables have an expected life of 50 years. The assets that exceeded (or are approaching) their end of life are:

- EP/W-HAY 81 132 kV cable
- EP/W-HAY 82 132 kV cable
- EP-W 71 66 kV cable
- EP-W 72 66 kV cable

The EP-W 71 and 72 transmission cables are operating beyond their design life and have condition issues which poses a high risk of failure even though extensive maintenance activities have moderately mitigated the condition issues in recent years. Failure of the cable may also pose a potential supply risk to customers as some of the distribution feeders are interconnected with HAY substation which is designed to Perth CBD (N-2) Criterion. Thus, also taking into consideration the issues mentioned at F and EP (66 kV) substations in the previous sections, the proposed long term strategy for these three substations (F, W & EP) is to decommission when practically feasible to do so.

3.2.5 Distribution Cables

Most distribution feeders supplied by HAY and MIL substations are configured to form feeder pairs. This configuration was historically implemented to provide security of supply for an N-2 transmission line event resulting in the total loss of supply to either HAY or MIL substations. In the event of this contingency, the feeder pairs enable the wholesale load transfer from one substation to the other by limiting the feeder loadings to 50%. The feeders in the outer CBD are also required to limit the feeder loadings if they are paired with HAY or MIL substations and provide transmission network support through DTC.

The high density of loads within the Perth CBD and the limiting of the distribution feeder capacity to 50% has increased the underground cable congestion, particularly for the cables exiting HAY or MIL substations. Moreover, installing more cables within the underground sections also de-rates the existing cables further resulting in lower utilisation of the full capacity of the cable.

3.2.6 Summary of Asset Condition

The overall asset condition in East Perth/CBD load area relating to the zone substations provides very strong support for the need to undertake a significant volume of asset replacement and retirement within the 25 year planning horizon. This will be staged and driven by the severity of the asset conditions. The first round of asset replacement will be required within the first 10 years, with issues needing to be addressed at EP (66 kV), F, MIL, HAY and W zone substations.

Some of the critical assets that are required to be addressed within this period are summarised in Table 4.

Table 4: Summary of critical asset in EP and CBD load area and proposed mitigation

Substation	Asset	Proposed Mitigation	Required by
HAY	Switchboard	Replacement of asset	2019
F	Switchboard	Offload F substation	2020
		Decommission F substation	2021
MIL	Switchboard	Replacement of asset	2021
W	EP-W 71/72 Line (cable) Transformers	Offload W substation	2022
		Decommission W substation	2023
EP	Stranded 66 kV assets	Decommission EP 66 kV	2027

The decommissioning of F substation in 2021 would require the transfer of the loads to adjacent substations in 2020. Similarly, the decommissioning of W substation would require the majority of the loads to be offloaded to HAY substation. However, the MIL substation switchboard replacement is proposed to be completed by 2021 and would transfer some of the loads to HAY substation to facilitate the replacement. Therefore, the offloading of W substation to HAY substation is only practically feasible in 2022 with decommissioning the following year.

Western Power has undertaken studies to optimise the offloading of the loads from F and W substations to existing substations through minimal reinforcements or switching based on the geographical locations of the respective feeders. It was concluded that approximately 28.3% and 75.3% from F and W substation respectively, at the year of transfer, would need to be offloaded to HAY substation. This is illustrated in Figure 7.

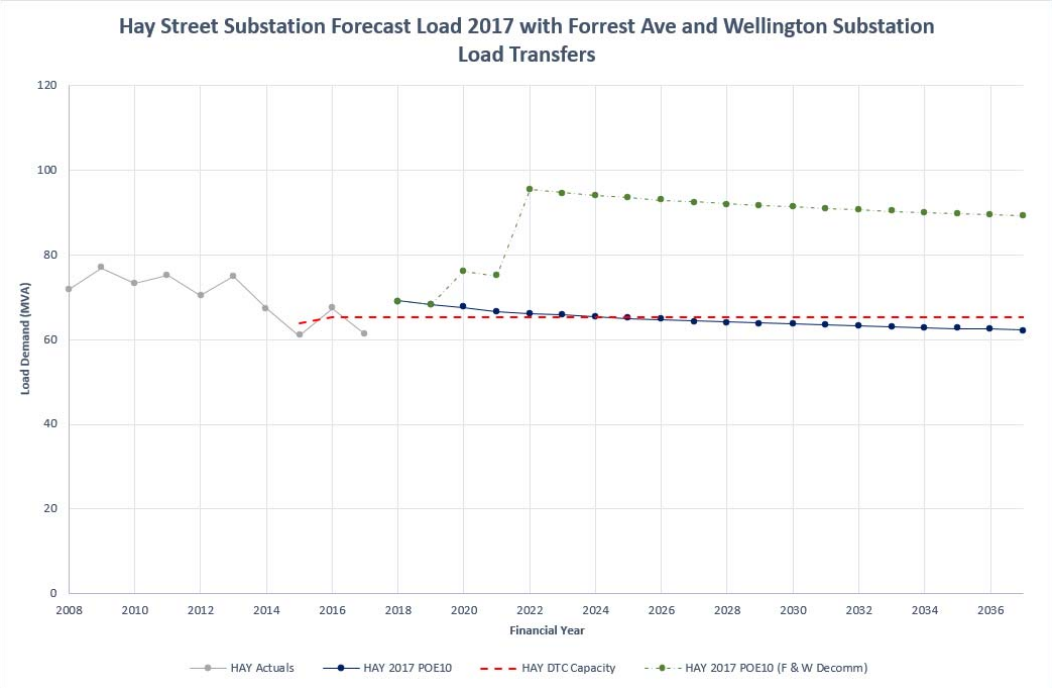

Figure 7: HAY Substation 2017 Forecast Load with F and W Substation Load Transfers in 2020 and 2025

Similarly, approximately 14.0% from W substation would need to be offloaded to MIL substation with the rest of the load from F and W substations being distributed to other substations in the outer CBD. This is shown in Figure 8.

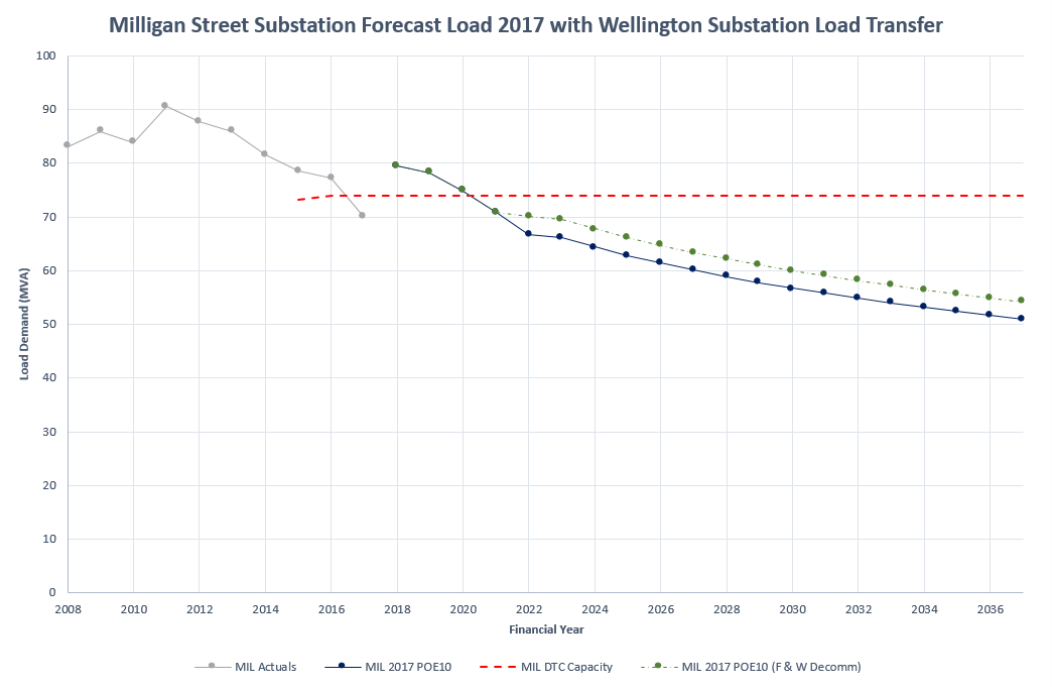

Figure 8: MIL Substation 2017 Load Forecast with W Substation Load Transfer in 2025

As detailed in Section 3.1, Western Power currently utilities DTC to achieve compliance with the Perth CBD Criterion. Based on this planning requirement, the available DTC effectively becomes the boundary for compliance, with any load above this value being non-compliant load at risk and requiring mitigation. This is shown as a dashed red line in Figure 7 and Figure 8 respectively.

The transfer of F substation load to HAY substation in 2020 results in approximately 10.9 MVA of load at risk (14.3% of HAY substation load in 2020) under an N-2 contingency event. This is inclusive of the load risk at HAY substation prior to the load transfer in 2020 of approximately 3.1 MVA (4.5% of HAY substation load in 2019).

The transfer of W substation load to HAY substation in 2025 increases the load at risk to approximately 25.5 MVA (28.1% of HAY substation load in 2025). The load at risk remains relatively flat beyond this period, decreasing only by a marginal amount.

MIL substation load forecast is forecast to be compliant after 2020 and is forecast to remain compliant regardless of the load transfer from W substation in 2025.

The proposed decommissioning of F and W substations results in EP (66 kV) terminal being a redundant asset and it is proposed to be decommissioned in 2027 as it is expected that extensive planning is required to decommission this site and the 66 kV transmission lines that emanate from this substation.

3.2.7 Other Considerations

The State Government is in the process of selling the (former) East Perth Power Station land for the purpose of redevelopment, including the land currently occupied by the EP 66 kV switchyard. This would require the switchyard to be relocated or decommissioned. As F and W substations are expected to be decommissioned in the next 10 years, the decommissioning of the EP 66 kV switchyard and the associated assets is a more likely option. There is also a need to ensure the alignment of timing of these works and the State Government's plans which is currently circa 2020.

4 Options Considered

4.1 Network Options

Western Power has carried out detailed planning studies to consider feasible network options to mitigate the asset condition issues summarised in Table 4. These studies included load flow analysis, fault level studies and other technical assessments to determine the capability of various options to adequately reduce the risk associated with the asset condition whilst also ensuring that the supply to future customer electricity needs in the EP and CBD load area are met.

From the planning studies and network options identified, five feasible development strategies to augment the transmission network in the EP and CBD load area were identified across the 10 year period. These were evaluated in detail and the net present cost of each of the options compared in accordance with the Regulatory Test. The five development strategy themes identified were:

1. Like for like replacement
2. CBD Substation
3. HAY-MIL cable
4. Minor distribution upgrades and defer HAY-MIL cable to 2022
5. Major distribution upgrades

The investments within all the development strategies have been included on the assumption of having started the planning activities in 2015 (or later) to achieve the required timeframes as detailed in section 3.2.6.

4.1.1 Option 1: Like for Like Replacement

The first development strategy considered is designed to maintain the existing 132 kV and 66 kV network assets and configuration, by addressing age and condition issues as required through in-situ replacements.

The staging and description of developments for this strategy is summarised in Table 5.

Table 5: Cost Breakdown for Development Strategy 1

Year Required	Substation	Proposed Augmentation	Nominal Cost ($M)
2019	HAY	Replacement of HAY substation switchboard	$31.2
2020	F	Rebuild F substation with: - Two 66/11 kV 33 MVA transformers - One double bus 11 kV switchboard	$31.4
2021	MIL	Replacement of MIL substation switchboard	$32.6
2022	W	Rebuild W substation with: - Two 66/11 kV 33 MVA transformers Replace EP-W 71 & 72 transmission cables	$51.1
2027	EP	Rebuild EP 66 kV Terminal	$69.7
		Total Capital Cost	**$216.0**
		Total Net Present Cost	**$172.2**

The rebuilding of F and W substations includes offloading of the respective substation loads to enable rebuilding and this includes (for each substation):

- Installation of four temporary Ring Main Units (RMU) with automation
- Installation of six new feeders to terminate at these RMUs
- Network reconfiguration, protection settings changes and switching as required

4.1.2 Option 2: CBD Substation

Development strategy 2 is designed to build a new CBD substation to cater for the future decommissioning of F and W substations through offloading the respective loads to the CBD and adjacent substations. This option also includes the decommissioning of any other redundant 66 kV assets (such as EP terminal) to mitigate the deteriorated condition of these assets.

The staging and description of developments for this strategy is provided in Table 6.

Table 6: Cost Breakdown for Development Strategy 2

Year Required	Substation	Proposed Augmentation	Nominal Cost ($M)
2019	HAY	Replacement of HAY substation switchboard	$31.2
2020	CBD	Build new CBD substation with: - Two 132/11/11 kV 60 MVA transformers - Two double bus 11 kV switchboards - Two 132 kV incoming circuits	$164.0
2020	F	Offload F to CBD and adjacent substations	$7.3
2021	MIL	Replacement of MIL substation switchboard	$32.6
2021	F	Decommission F substation	$1.3
2022	W	Offload W to CBD and adjacent substations	$7.9
2023	W	Decommission W substation	$1.4
2027	EP	Decommission EP 66 kV Terminal	$4.4
		Total Capital Cost	**$250.1**
		Total Net Present Cost	**$244.6**

4.1.3 Option 3: HAY-MIL Cable

Development strategy 3 is designed to build a new 132 kV transmission cable between HAY and MIL substations to cater for the offloading and decommissioning of F and W substations. The new 132 kV cable is required to meet Perth CBD Criterion compliance requirements after the offloading of F and W substations. This option also includes the decommissioning of any other redundant 66 kV assets (such as EP terminal) to mitigate the deteriorated condition of these assets.

The staging and description of developments for this strategy is provided in Table 7.

Table 7: Cost Breakdown for Development Strategy 3

Year Required	Substation	Proposed Augmentation	Nominal Cost ($M)
2019	HAY	Replacement of HAY substation switchboard	$31.2
2019	HAY & MIL	Install new 132 kV transmission cable between HAY and MIL substations (2000mm^2 copper XLPE)	$38.5
2020	F	Offload F to HAY and adjacent substations	$17.0
2021	MIL	Replacement of MIL substation switchboard	$32.6
2021	F	Decommission F substation	$1.3
2022	W	Offload W to HAY and adjacent substations	$11.9
2023	W	Decommission W substation	$1.4
2027	EP	Decommission EP 66 kV Terminal	$4.4
		Total Capital Cost	**$138.3**
		Total Net Present Cost	**$128.2**

4.1.4 Option 4: Minor Distribution Upgrades and Defer HAY-MIL cable

Development strategy 4 is a variation of Development Strategy 3, with the deferment of the new 132kV transmission cable preceded by minor distribution reinforcements whilst meeting compliance with Perth CBD Criterion. All other decommissioning and asset replacement works are similar to Development Strategy 3.

The staging and description of developments for this strategy is provided in Table 8.

Table 8: Cost Breakdown for Development Strategy 4

Year Required	Substation	Proposed Augmentation	Nominal Cost ($M)
2019	HAY	Replacement of HAY substation switchboard	$31.2
2019	HAY & MIL	Minor distribution reinforcements at HAY, MIL and adjacent substations	$6.2
2020	F	Offload F to HAY and adjacent substations	$17.0
2021	MIL	Replacement of MIL substation switchboard	$32.6
2021	F	Decommission F substation	$1.3
2022	HAY & MIL	Install new 132 kV transmission cable (2000mm^2 copper XLPE)	$46.5
2022	W	Offload W to HAY and adjacent substations	$11.9
2023	W	Decommission W substation	$1.4
2027	EP	Decommission EP 66 kV Terminal	$4.4
		Total Capital Cost	**$152.5**
		Total Net Present Cost	**$134.4**

4.1.5 Option 5: Major Distribution Upgrades

Development strategy 5 is designed to undertake major distribution reinforcements at HAY, MIL and adjacent substations to cater for the offloading and decommissioning of F and W substations. The distribution reinforcements are required to meet Perth CBD Criterion compliance requirements after the offloading of F and W substations. This option also includes the decommissioning of any other redundant 66 kV assets (such as EP terminal) to mitigate the deteriorated condition of these assets.

The staging and description of developments for this strategy is provided in Table 9.

Table 9: Cost Breakdown for Development Strategy 5

Year Required	Substation	Proposed Augmentation	Nominal Cost ($M)
2019	HAY	Replacement of HAY substation switchboard	$31.2
2019	HAY & MIL	Major distribution reinforcements at HAY, MIL and adjacent substations	$54.1
2020	F	Offload F to HAY and adjacent substations	$17.0
2021	MIL	Replacement of MIL substation switchboard	$32.6
2021	F	Decommission F substation	$1.3
2022	W	Offload W to HAY and adjacent substations	$11.9
2023	W	Decommission W substation	$1.4
2027	EP	Decommission EP 66 kV Terminal	$4.4
		Total Capital Cost	**$153.9**
		Total Net Present Cost	**$144.0**

4.2 Non Network Options

Non-network solutions in the EP and CBD load area could take the form of local generation (as a network control service) and Demand Side Management (DSM).

The benefits of DSM arise from the net monetary saving obtained by deferring reinforcement investment to later years. These benefits are calculated in Net Present Cost (NPC) terms for comparison with the costs of other options.

The recommended investment is seeking to address aged and deteriorated asset condition issues in the EP and CBD load area which results in an increase in non-compliant load at HAY substation in future years. The deferral of the asset replacement or retirements beyond the recommended investment period is not preferred. Hence, non-network solution is discounted as a feasible solution.

5 Format and Inputs to Analysis

5.1 Regulatory Test Requirements

The Regulatory Test is an assessment under Chapter 9 of the Electricity Networks Access Code 2004 of whether a proposed Major Augmentation to a covered network maximises the Net Benefit (measured in present value terms to the extent that it is possible to do so) to those who generate, transport or consume electricity after considering alternative options.

Western Power's proposed Major Augmentation is considered defensible if it applies the Regulatory Test properly using reasonable market scenarios and varying levels of growth at relevant places. Western Power must also use reasonable timings for project commissioning dates and construction timetables.

The Regulatory Test Guidelines[5] provide direction in identifying methods for determining which option maximises Net Benefits. Areas to be considered for analysis should include but not be limited to construction, operation and maintenance costs, changes to fuel consumption arising through different generation dispatch, changes in voluntary load curtailment caused through reduction in demand side curtailment, changes in ancillary services and changes in involuntary load shedding caused through savings in reduction in lost load.

5.2 Cost of Network Augmentations

The financial analysis considers all foreseeable cost impacts of the proposed network augmentations. The cost to implement each of the feasible options outlined in Section 4 has been estimated by Western Power. The capital cost estimates utilised in this assessment have been derived from the Western Power estimating building blocks.

The Western Power building block cost estimates have been developed using the Western Power Estimation and Value Assurance's Success Estimator software and database for standard design and typical engineering parameters as well as by investigating historical cost figures and typical expenditure.

Where required, input was also sought from technical specialists within Western Power to gain expert knowledge on specific items to reduce the tolerance on estimates. A sensitivity analysis to the cost estimates for each option has been included in the Financial Analysis (Section 6).

5.3 Other Inputs to Analysis

While this Regulatory Test is specifically about the investment for the installation of a new 132 kV cable between HAY and MIL substation to address the identified requirements at this site in the medium term, the economic analysis compares development scenarios for the entire EP and CBD load area out until 2042.

The timing of the components for each strategy is based on meeting the Western Power central load forecast, as published in the Western Power 2017 Annual Planning Report. The actual timing of the anticipated investments may change as a result of the ongoing review of load forecasts for the EP and CBD load area during the 25 year planning horizon.

[5] Refer to https://www.erawa.com.au/electricity/electricity-access/guidelines/regulatory-test-guidelines

6 Financial Analysis

The economic analysis undertaken considered the net present cost of alternative options over the 25 year period from 2017/18 to 2042/43.

6.1 Net Present Cost Analysis

The previous sub-sections have presented the details of the individual development strategies considered for the EP and CBD load area, as well as key financial and technical parameters associated with each. This section now brings the strategies together to contrast and compare the costs and benefits of each in order to identify the optimal strategy for the EP and CBD load area over the next 25 years. Table 2 provides a summary of the NPC assessment for the identified strategies.

The analysis also provides the snapshot of the network capacity benefit that could be achieved through the investments even though the primary drivers for the investments are asset condition. It is evident from Table 2 that the strategy with the lowest NPC is development strategy 3 which also provides the largest transmission and distribution network capacity benefit and will facilitate the eventual decommissioning of F and W substations in 2021 and 2023 respectively.

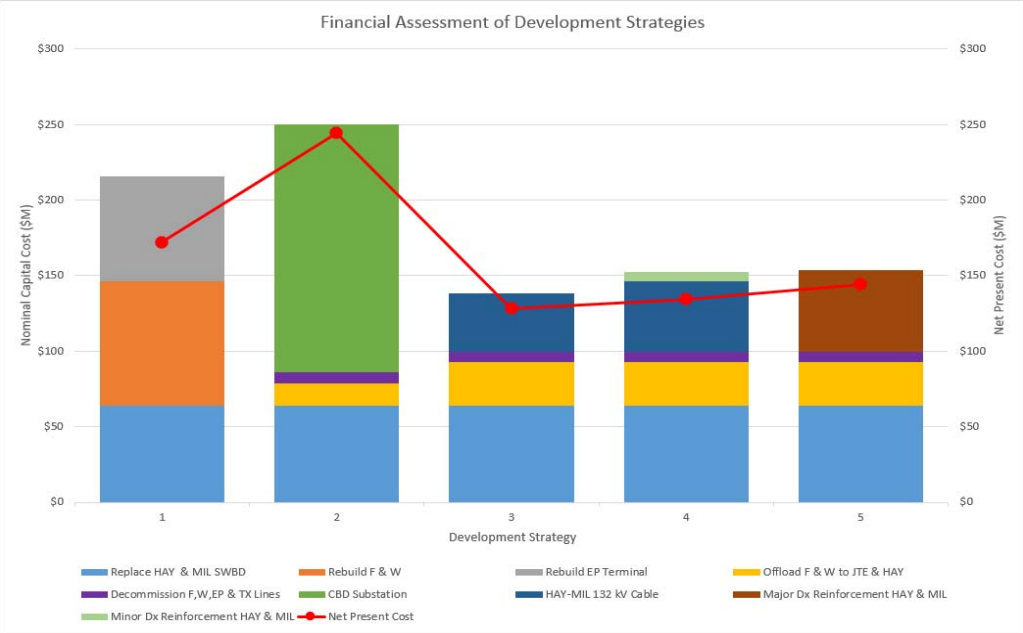

Figure 9: Financial Assessment of Development Strategy

The development strategies have common investment cost which, when removed from the financial analysis, provides the distinct investment options as illustrated in Figure 9.

The expenditure profile of the development strategies considered is illustrated in Figure 10. Development strategy 3 requires a greater upfront investment in the first four years compared with development strategy 1 and 5. However, when compared across the 10 year period, it compares favourable against these two strategies which require lower upfront capital investment. This demonstrates that development strategy 3 provides the long term financial benefit whilst addressing the aged and deteriorated asset condition drivers.

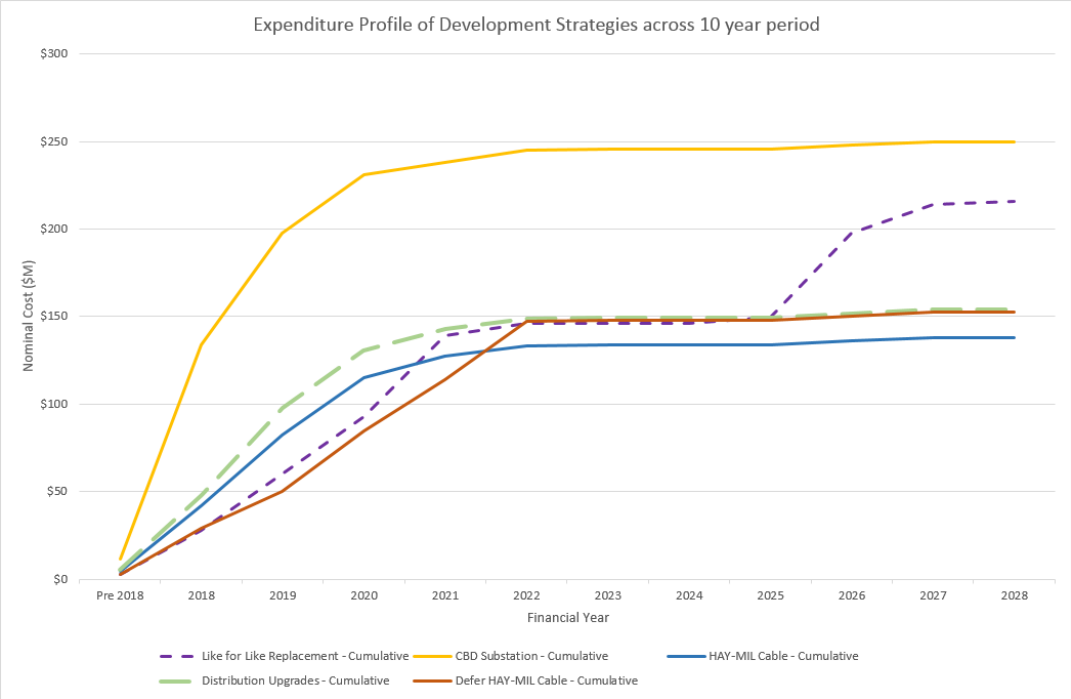

Figure 10: Expenditure Profiles of Development Strategies across 10 year period

6.2 Sensitivity Analysis

6.2.1 Cost Building Blocks

As outlined in Section 4, the total capital cost calculated for each development strategy has been based on the required number of asset units using the Western Power estimating building blocks. The building blocks provide an average cost based on historical values and are not fully detailed taking into account any site specific requirements. It is expected that these costs would be subject to a degree of variation and revision when developed in detail.

The costs considered in the development strategy comparisons have generally been prepared with a tolerance of ±20%. The only exception to this is the cost of the new 132 kV transmission cable between HAY and MIL substations which has been estimated through the Western Power's Estimation and Value Assurance Section based on preliminary design (±10% tolerance).

Cost sensitivity analysis on the NPC was also undertaken using Western Power's Investment Evaluation Model (IEM) with a variance of ±20% to the overall expenditure across the evaluation period. This is illustrated in Table 10.

Table 10: Cost Sensitivity Analysis on NPC on Total Expenditure

Strategy	Base Case	Ranking	High State (+20%)	Ranking	Low State (-20%)	Ranking
1	$172.2	4	$206.6	4	$137.7	4
2	$244.6	5	$292.1	5	$197.1	5
3	$128.2	1	$153.5	1	$102.9	1
4	$134.4	2	$160.9	2	$107.9	2
5	$144.0	3	$172.3	3	$115.7	3

Cost sensitivity analysis on the distinct investment options indicated that development strategy 3 is robust against ±20% cost variations, and therefore remains the most financially prudent (and recommended) option when assessed under these scenarios.

6.2.2 Demand Growth

The primary driver underpinning the required reinforcement is the culmination of asset conditions in the EP and CBD load area. The mitigation solutions for the decommissioning of F and W are the key differences between the investments considered. Development strategies 3 and 4, with the installation of a new 132 kV transmission cable between HAY and MIL substations, provide an additional capacity benefit to both the distribution and transmission networks.

The 2017 load forecast depicts a downward trend in the future electricity demand for the substations in the EP and CBD load area. The nature of the customer demand in this load area is very dynamic and could materialise rapidly into positive load growth, driven by large customer block load connections and increased occupancy rates. Major developments in Perth CBD, such as those within Elizabeth Quay and Perth City Link illustrates this as they are either in planning, construction or are not operating at full demand capacity. When this demand increase occurs, the network would need to be reactive to cater to the increased demand in a safe, efficient and reliable manner. The capacity benefits that can be realised through the preferred option would cater for this future load growth scenario.

The demand growth sensitivity analysis considers a +1% and -1% annual growth for the next 25 years over and above the load growth included in the 2017 load forecast. These have been considered as a high and low growth scenarios respectively and only the substations where the asset condition and investment drivers are applicable have been assessed which are HAY, MIL, F and W substations.

Table 11 illustrates the outcomes of the demand growth sensitivity analysis on the NPC.

Table 11: Demand Growth Sensitivity Analysis

Development Strategy	Base Case NPC ($M)	Low Growth Impact		High Growth Impact	
		Description	Revised NPC ($M)	Description	Revised NPC ($M)
1	$172.2	No change to investment strategy	$172.2	Mitigation at HAY substation required	$178.4
2	$244.6	No change to investment strategy	$244.6	Mitigation at HAY substation required	$250.8
3	$128.2	No change to investment strategy	$128.2	No change to investment strategy	$128.2
4	$134.4	No change to investment strategy	$134.4	No change to investment strategy	$134.4
5	$144.0	Reduced major distribution upgrades	$137.1	Mitigation at HAY substation required	$151.6

The demand growth sensitivity analysis indicates that with a high and low growth scenario, the investment pathway for development strategy 3 remains the most prudent and efficient investment pathway to mitigate the issues identified at EP and CBD load area.

Further details on the growth sensitivity analysis is provided in Appendix C.

7 Conclusions

The following conclusions have been drawn from the analysis presented in this report:

- 'Do nothing' is not an acceptable option as the primary drivers (asset age and condition) and associated safety, reliability and compliance risks would not be resolved. Furthermore, 'doing nothing' is also not consistent with good industry practice and Western Power's obligations to comply with the requirements of the Technical Rules and the Electricity Networks Access Code 2004.
- Western Power must plan and coordinate works to allow adequate lead time to ensure reliable electricity supply to the EP and CBD load area is maintained through the implementation of the preferred development strategy to meet in-service requirements.
- Planning studies were undertaken to evaluate potential network options to address the future supply requirements in the EP and CBD load area. Five development strategies were evaluated against a range of financial and technical performance metrics to determine the most efficient and prudent investment pathway.
- Economic analysis carried out as part of this assessment has identified that development strategy 3 is the least NPC cost solution over the 25-year period of the analysis. The results of sensitivity analysis involving variation in cost and load growth also demonstrate an outcome consistent with the base case economic analysis, in that the options ranking does not change. Development strategy 3 is therefore considered to maximise net benefits when considering alternative options.
- The first key investment of this development strategy is the installation of a 132 kV interconnecting transmission cable between HAY and MIL substations and associated works in a staged approach by 2020. The nominal capital cost of this option is $38.5 million (including project on costs and risk allowance).

8 Draft Recommendation

Based on the conclusion drawn from the analysis and Western Power obligations under the Electricity Networks Access Code 2004 for Major Augmentations it is recommended that the following investments be taken forward.

By 2019:

- The installation of a new 132 kV transmission cable between HAY and MIL substations with the following specifications:
  - 1.95 km of 2000mm^2 copper conductor, XLPE insulated cable type to achieve 240 MVA summer rating
  - Proposed cable route as shown in Appendix A
- The installation of associated equipment at HAY and MIL substations to enable the connection of the new cable with AIS switchgear at HAY and GIS switchgear at MIL

By 2020:

- Mitigation of any under fault rated assets through the increased fault levels (due to the cable installation) at HAY, MIL and neighbouring substations.

The nominal capital cost of this option is $38.5 million (including project on costs and risk allowance) and has been determined as part of the detailed cost estimate process through Western Power's Estimation and Value Assurance Section. This solution is a key decision that sets the investment direction for the wider EP and CBD area to ensure that the asset age and condition issues, in particular, are addressed in a timely manner.

It should be noted that the draft recommended strategy for the EP and CBD load area is Strategy 3 and that the investments identified within it will be taken forward in due course. Some of these investments may be the subject of future Regulatory Tests.

9 Consultation

In accordance with the Electricity Networks Access Code 2004 Western Power invites submission from all interested parties on this Options Paper

Submissions are due by 7 August 2017.

Please address all submissions to:

Brett Miller
Team Leader, Network Solutions Scoping
CBD Supply Reinforcement
Network Planning
Western Power
GPO Box L921
Perth WA 6842
Tel (08) 9326 4197
Cbd.supply.reinforcement@westernpower.com.au

Following consideration of all received submissions, Western Power expects to publish a final recommendation in August 2017.

Appendix A: Proposed 132 kV Transmission Cable Route between HAY and MIL Substations

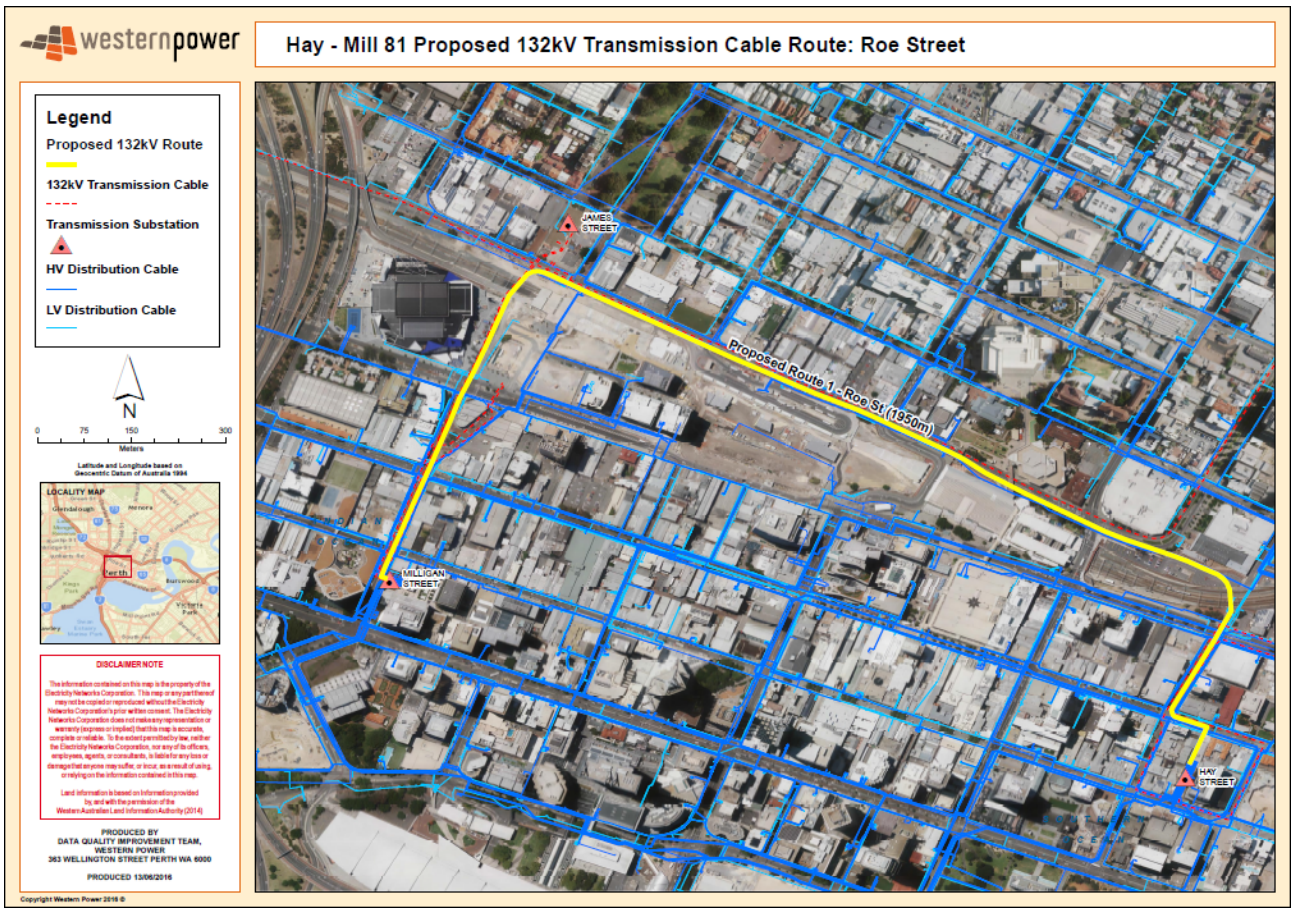

Figure 11: Proposed 132 kV Transmission Cable Route between HAY and MIL Substations

Appendix B: Asset Condition in EP and CBD Load Area

Zone Substation Transformers

The age and asset condition of the zone substation transformers in the EP and CBD load area is shown in Table 12. The transformers are divided into three nominal voltage categories; 132/66 kV, 132/11 kV and 66/11 kV transformers.

Table 12: Condition of Zone Substation Transformers in the East Perth and CBD Load Area

Substation Transformer	Nameplate Voltage		Capacity (MVA)	Age (Years)	Asset Health Condition[6]
	HV (kV)	LV (kV)			
East Perth T3	132	69	100.0	49	Fair
East Perth T5	132	69	100.0	49	Fair
Forrest Avenue T1	66	12	39.6	47	Poor
Forrest Avenue T2	66	12	39.5	47	Poor
Hay Street T1	132	12/12	77.2	39	Poor
Hay Street T2	132	12/12	84.8	17	Good
Hay Street T3	132	12/12	76.9	39	Fair
Milligan Street T1	132	12/12	76.6	43	Fair
Milligan Street T2	132	12/12	63.0	27	Good
Milligan Street T3	132	12/12	77.1	43	Fair
Wellington Street T1	66	12	28.6	50	Fair
Wellington Street T2	66	12	28.6	50	Poor

Switchboards

The age and condition of the zone substation switchboards in the EP and CBD load area is shown in Table 13. There are no switchboards at EP terminal substation.

[6] Based on Condition Based Risk Management (CBRM) health index obtained through Western Power asset data. Assets with a CBRM of 'Fair' has approximately between 40% and 60% of remaining asset life while 'Poor' has approximately between 20% and 40% of remaining asset life.

Table 13: Condition of Switchboards in the East Perth and CBD Load Area

Substation	Switchboard No	Age (Years)	Current Condition
Forrest Avenue	1	47	Reached expected end of life
	2	47	Reached expected end of life
Hay Street	1	39	Reached expected end of life
	2	11	No issues
	3	27	No issues
Milligan Street	1	43	Reached expected end of life
	2	11	No issues
	3	27	No issues
Wellington Street	1	18	No issues
	2	18	No issues

Transmission Wood Poles and Steel Structures

The expected life of transmission wood poles and steel structures is 40 and 50 years respectively. Most of the assets are approaching or have reached their end of life and this is illustrated in Table 14. The 132 kV line structures are expected to be replaced with like for like replacement or reinforced in the future. The 66 kV line structures are expected to be decommissioned once the other 66 kV assets at EP, W and F have been retired.

Table 14: Condition of Transmission Wood Pole and Steel Structures

Transmission Line	Wood Poles				Steel Structures			
	Total	Ave Age (years)	>40 years	End of life %	Total	Ave Age (years)	>50 years	End of life %
EP-F 71 (66 kV)	11	29	4	36%	2	29	2	100%
EP-F 72 (66 kV)	15	36	9	60%	2	36	2	100%
EP-EP 81	-	-	-	-	6	20	-	-
EP-EP 82	-	-	-	-	3	15	-	-
EP-W/HAY 81	1	32	-	-	15	32	-	-
EP-W/HAY 82	1	29	-	-	15	29	-	-
MLA-MIL 81	4	39	4	100%	38	39	-	-
MLA-MIL 82	2	39	2	100%	37	39	-	-
Totals	34	-	19	56%	118	-	4	3%

Transmission Lines

The condition of the transmission cables in the EP and CBD load area is summarised in Table 15.

Table 15: Condition of Transmission Cables in the East Perth and CBD Load Area

Cable Section	Age (years)	Type	Current Condition
EP/W-HAY 81	40	Oil filled cable	Degraded condition and approaching expected end of life
EP/W-HAY 82	40	Oil filled cable	Degraded condition and approaching expected end of life
EP-W 71 (66 kV)	67	Oil filled cable	Degraded condition and beyond expected end of life
EP-W 72 (66 kV)	66	Oil filled cable	Degraded condition and beyond expected end of life
EP-F 71 (66 kV)	22	XLPE	No issues
EP-F 72 (66 kV)	22	XLPE	No issues

Appendix C: Demand Growth Sensitivity Analysis

Development Strategy 1

This development strategy is designed to utilise the existing 132 kV and 66 kV network to improve the capacity and condition of the assets with in-situ replacements as required and this is detailed in Section 4.1.1.

The high and low growth scenarios for the substations are shown in Figure 12, Figure 13, Figure 14 and Figure 15 for F, W, HAY and MIL substations respectively.

The analysis indicates that for F and W substations, the proposed reinforcements would cater for any high growth scenarios as both substations are rebuilt with a firm capacity of 33.0 MVA.

HAY substation is forecast to be above the DTC capacity from 2018[7], resulting in approximately 3.9 MVA of load at risk. The current forecast indicates that with a negative load trend, the load at risk would be reduced to less than 1.0 MVA by 2022 and to zero by 2025. The low growth scenario facilitates to reduce the load at risk to zero by 2021. However, the high growth scenario exacerbates the load at risk requiring reinforcements to mitigate this.

MIL substation is also forecast to be above the DTC capacity from 2018. However, this non-compliant load is expected to diminish from 2020 based on the 2017 load forecasts and considering that Western Power has discussed a Technical Rules exemption request till 2020 with proposed mitigation strategies in place, no network reinforcement is required to address this marginal non-compliance at MIL substation.

The most efficient and prudent option to mitigate the load at risk during a high growth scenario is through minor distribution upgrades at an estimated cost of $6.2 million by 2019. This would mitigate approximately 10.7 MVA of load at risk which would cater for the high growth till 2037.

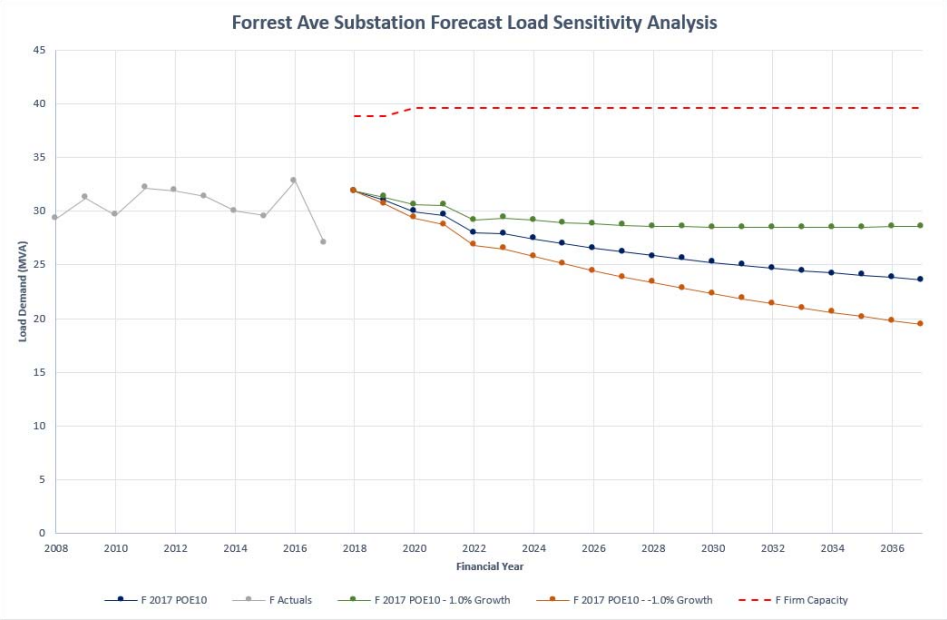

Figure 12: F Substation Forecast Load Sensitivity Analysis for Development Strategy 1

[7] HAY and MIL substations were non-compliant (albeit marginally) in 2015 based on actual load data.

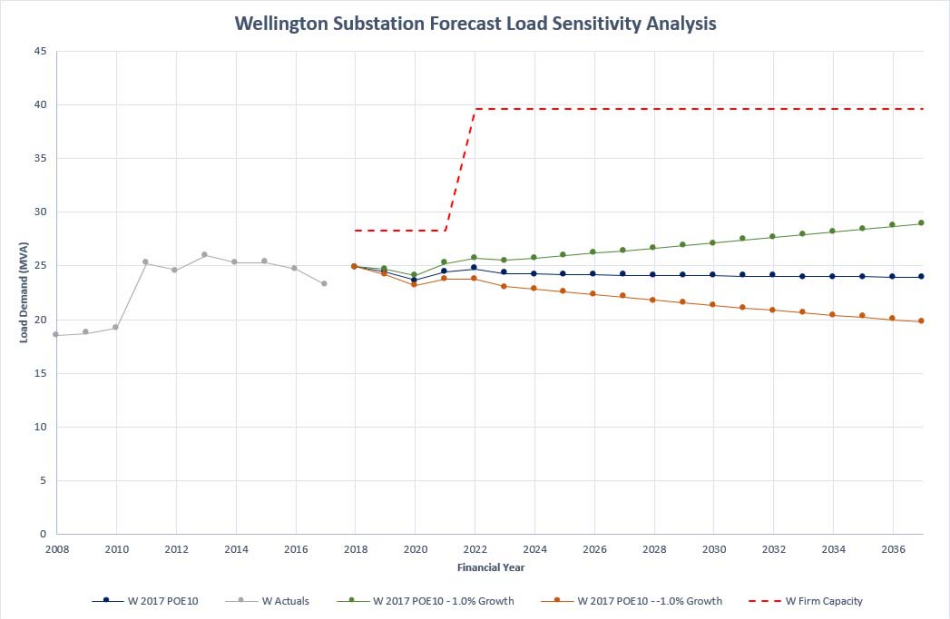

Figure 13: W Substation Forecast Load Sensitivity Analysis for Development Strategy 1

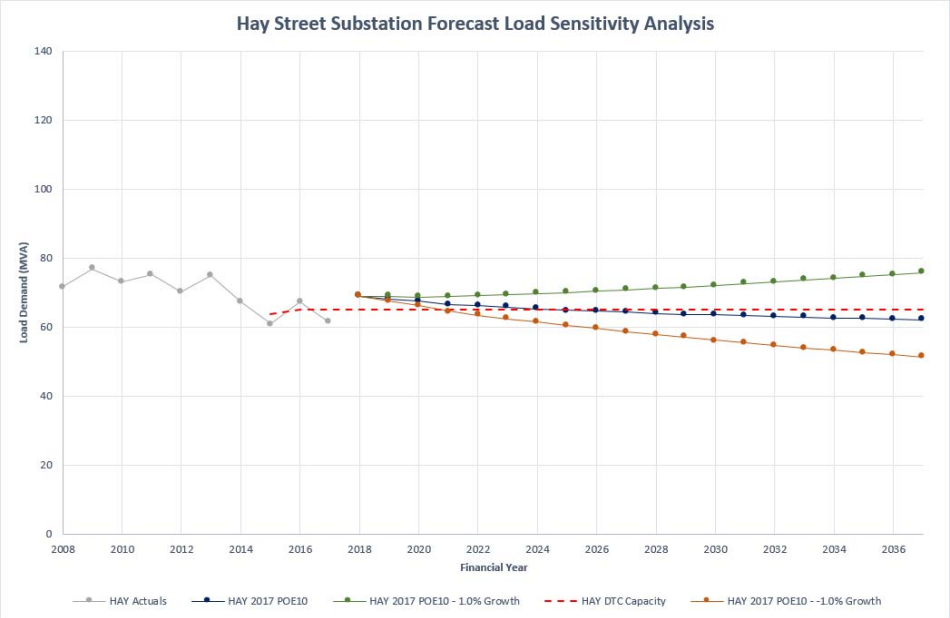

Figure 14: HAY Substation Forecast Load Sensitivity Analysis for Development Strategy 1

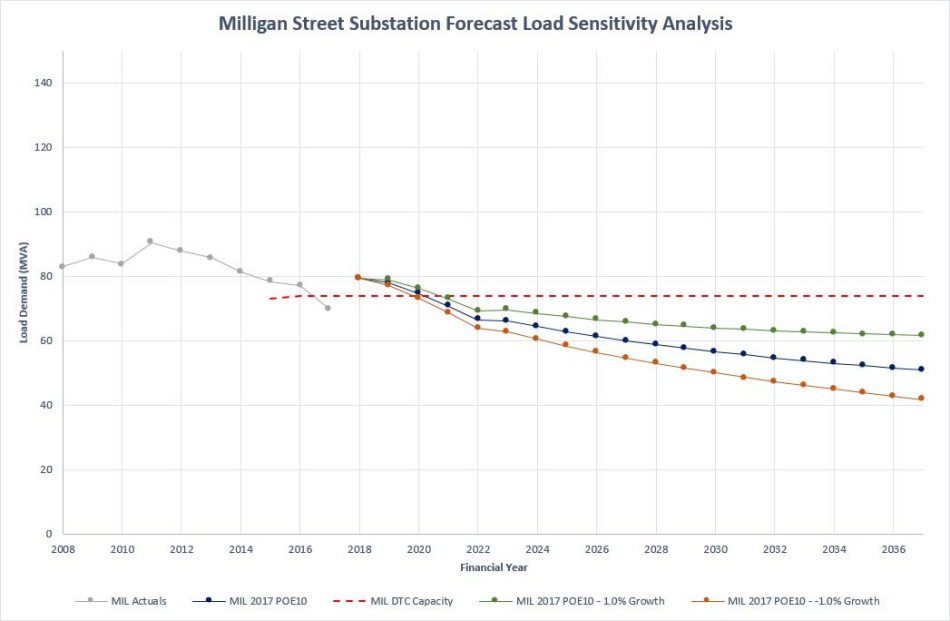

Figure 15: MIL Substation Forecast Load Sensitivity Analysis for Development Strategy 1

Development Strategy 2

This development strategy is designed to build a CBD substation to cater for the future decommissioning of F and W substations and this is detailed in Section 4.1.2.

The high and low growth scenarios for the HAY and MIL substations in development strategy 1 (as shown in Figure 14 and Figure 15 for HAY and MIL substations respectively) would also be applicable for this option. Thus, development strategy would also require a minor distribution upgrades at an estimated cost of $6.2 million by 2019.

F and W substations are expected to be offloaded to the new CBD substation which would be designed to cater for any potential high growth scenarios. This is shown in Figure 16 and Figure 17.

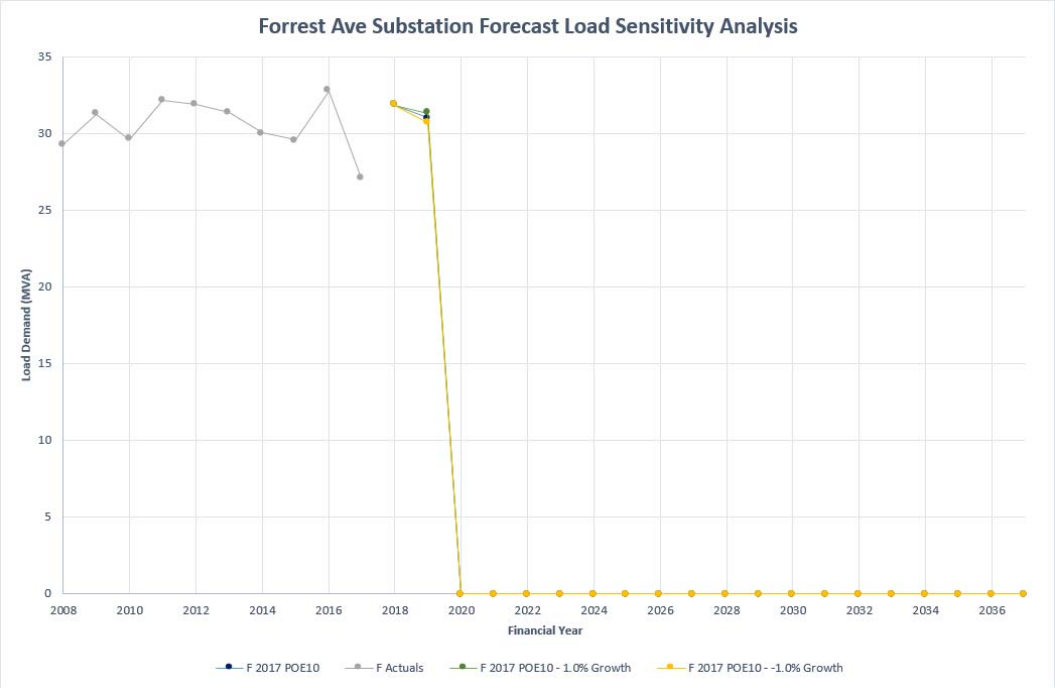

Figure 16: F Substation Forecast Load Sensitivity Analysis for Development Strategy 2

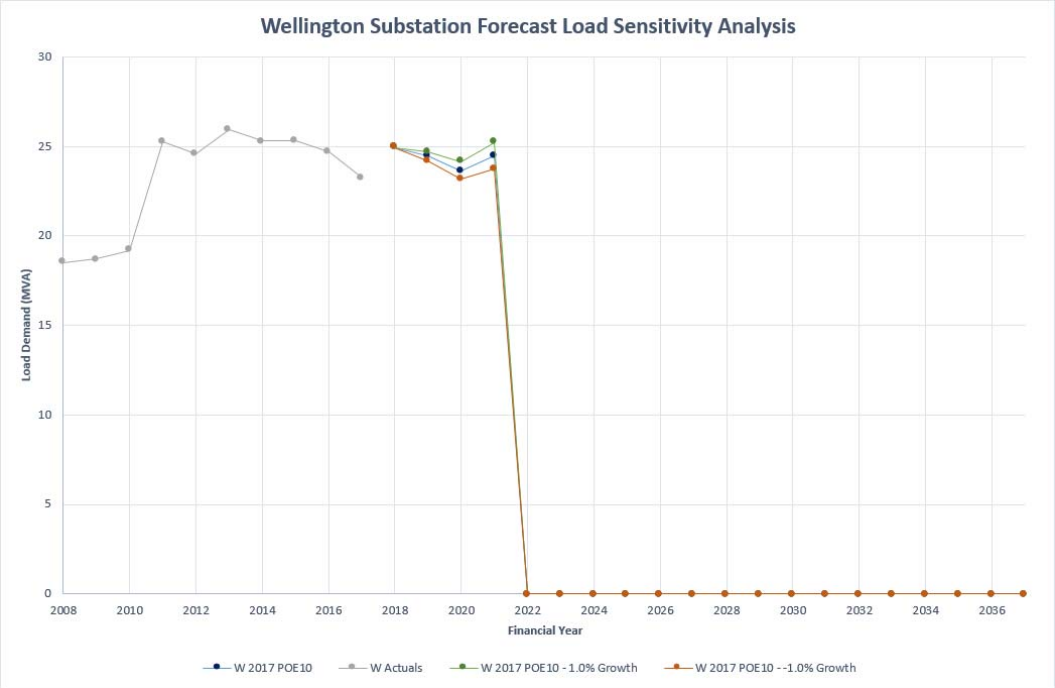

Figure 17: W Substation Forecast Load Sensitivity Analysis for Development Strategy 2

Development Strategy 3

This development strategy is designed to build a new 132 kV transmission cable between HAY and MIL substations to cater for the offloading of F and W substations and this is detailed in Section 4.1.2.

As shown in Figure 12 and Figure 13, high growth scenario for F and W substations are forecast to be within their capacity limits until the loads are transferred to adjacent substations.

The installation of the 132 kV transmission cable between HAY and MIL substations increases the total transfer capacity to 135.2 MVA and 143.9 MVA.[8] The high growth scenario for HAY and MIL substations indicate that there is sufficient capacity created and no additional reinforcements are required in the future. These are shown in Figure 18 and Figure 19.

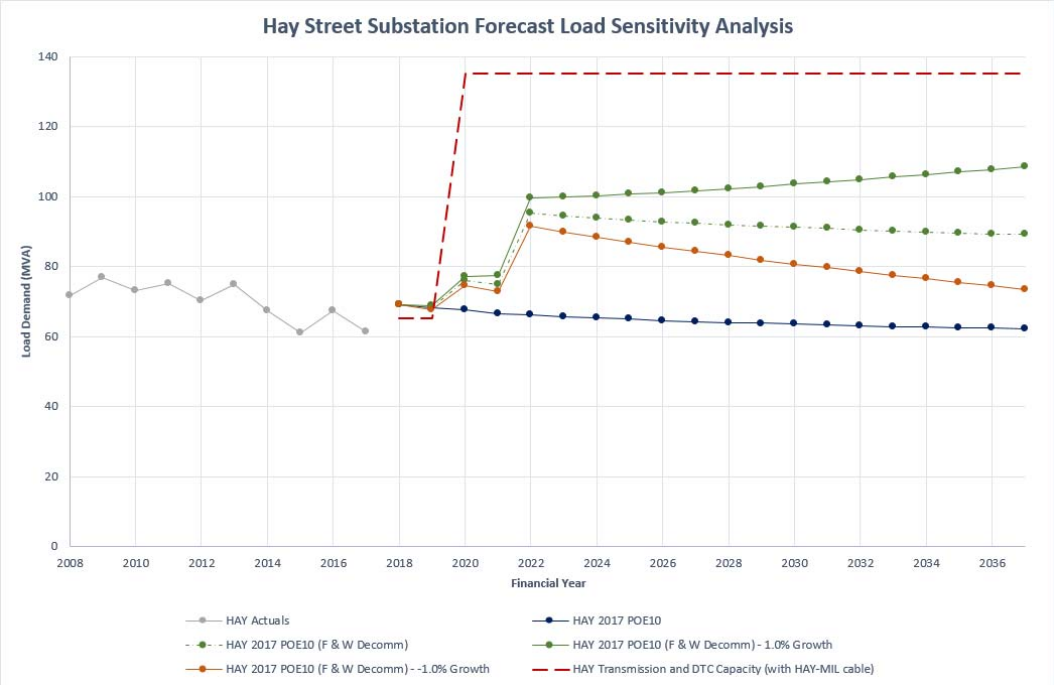

Figure 18: HAY Substation Forecast Load Sensitivity Analysis for Development Strategy 3

[8] Existing distribution transfer capacity of 65.2 MVA and 73.9 at HAY and MIL substations respectively and new transmission capacity of 70 MVA

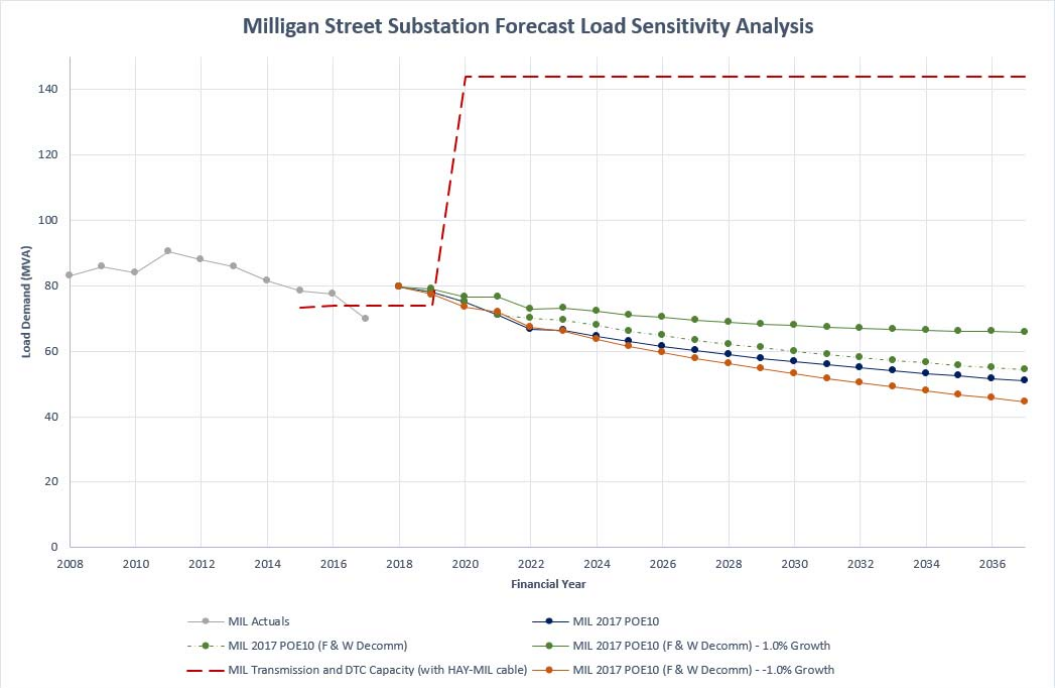

Figure 19: MIL Substation Forecast Load Sensitivity Analysis for Development Strategy 3

Development Strategy 4

This development strategy is designed to defer the build of a new 132 kV transmission cable between HAY and MIL substations by two years preceded by minor distribution reinforcements to cater for the offloading of F and W substations and this is detailed in Section 4.1.4.

Similar to development strategy 3, high growth scenario for F and W substations are forecast to be within their capacity limits until the loads are transferred to adjacent substations.

Likewise, the high growth scenario for HAY and MIL substations indicate that there is sufficient capacity created and no additional reinforcements are required in the future. These are shown in Figure 20 and Figure 21.

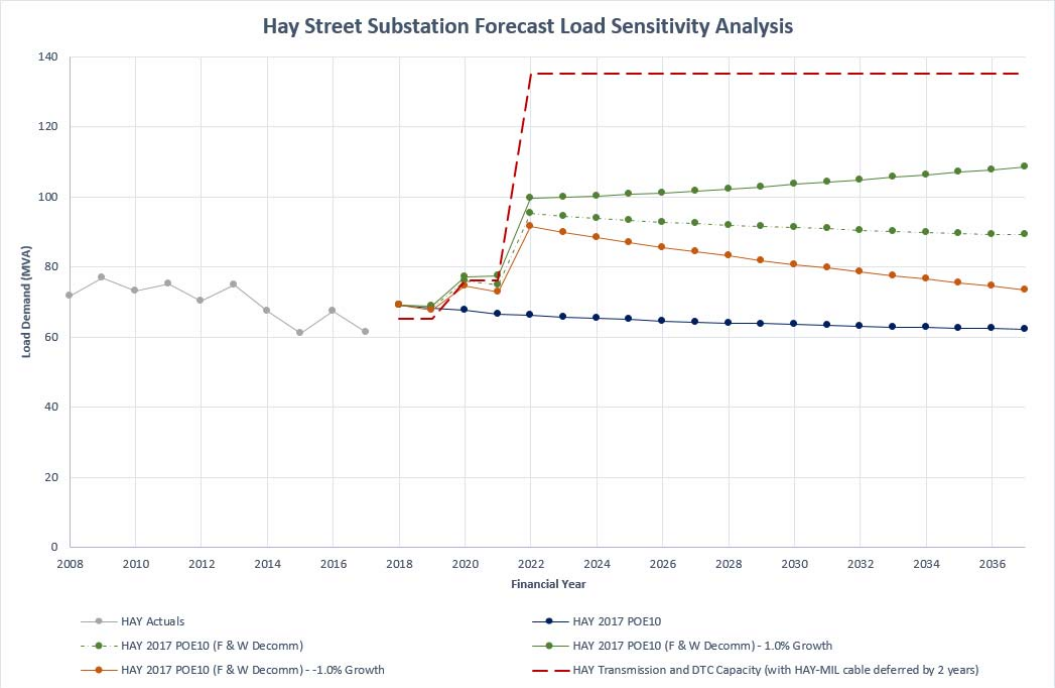

Figure 20: HAY Substation Forecast Load Sensitivity Analysis for Development Strategy 4

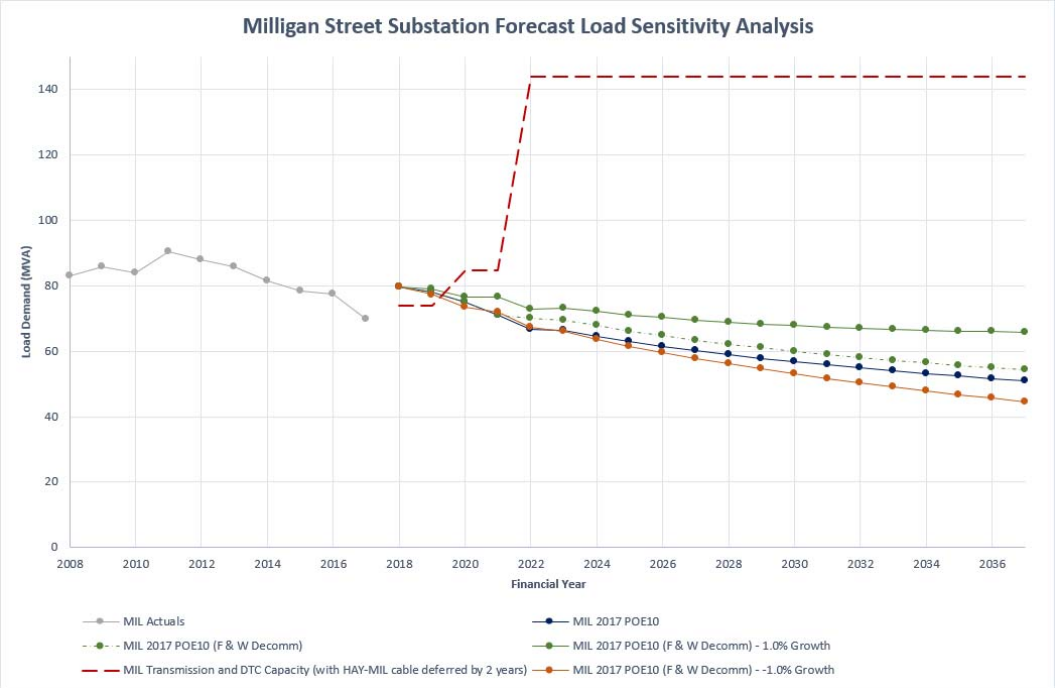

Figure 21: MIL Substation Forecast Load Sensitivity Analysis for Development Strategy 4

Development Strategy 5

This development strategy is designed to undertake major distribution reinforcements at HAY, MIL and adjacent substations to cater for the offloading of F and W substations and this is detailed in Section 4.1.5.

Similar to development strategies 3 and 4, high growth scenario for F and W substations are forecast to be within their capacity limits until the loads are transferred to adjacent substations.

Major distribution works would be increase the DTC at HAY substation from 65.2 MVA to 95.4 MVA. However, whilst this caters for the load at risk from 2019 for the base case scenario, the high growth scenario exposes potential load at risk in the future that would need to be mitigated. Thus, additional minor distribution upgrades are required in 2020 at an estimated cost of $9.1 million that would mitigate approximately 13.3 MVA of load at risk which would cater for the high growth till 2037.

A low growth scenario at HAY substation implies that the same level of major distribution upgrades may not be required to cater for the significant load at risk in 2022 (if unmitigated). The load at risk in 2020 is 30.2 MVA and 26.4 MVA for base case and low growth scenarios respectively. The base case load at risk was to be mitigated at an estimated cost of $50.1 million. Assuming that distribution upgrades costs are linear, this could potentially reduce the distribution cost by about 12.6% to $47.2 million.

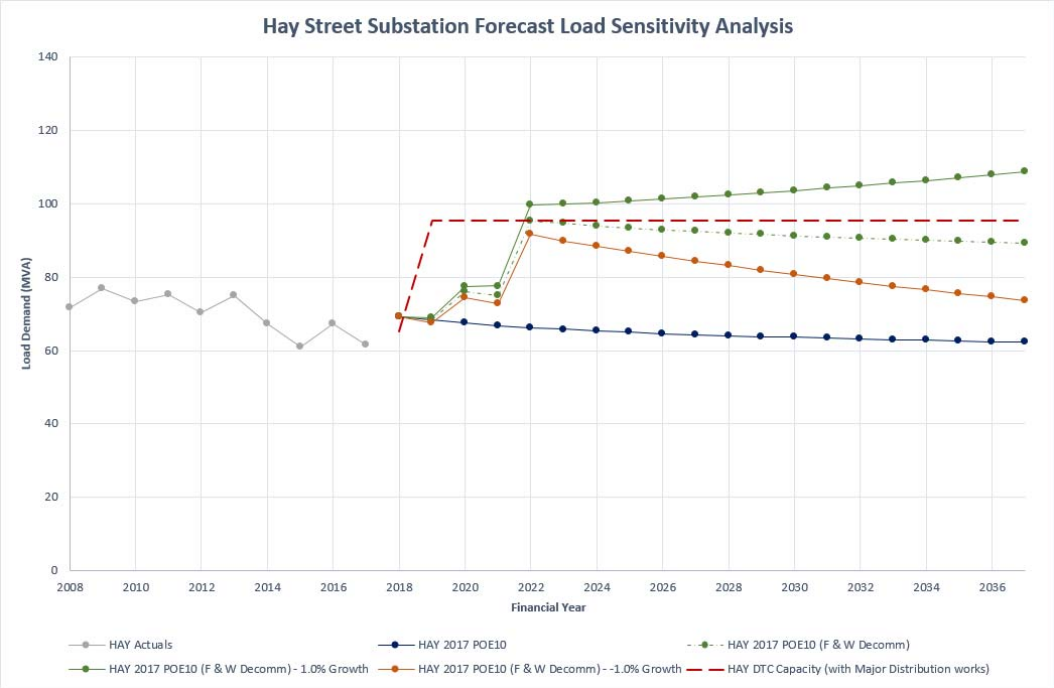

Figure 22: HAY Substation Forecast Load Sensitivity Analysis for Development Strategy 5

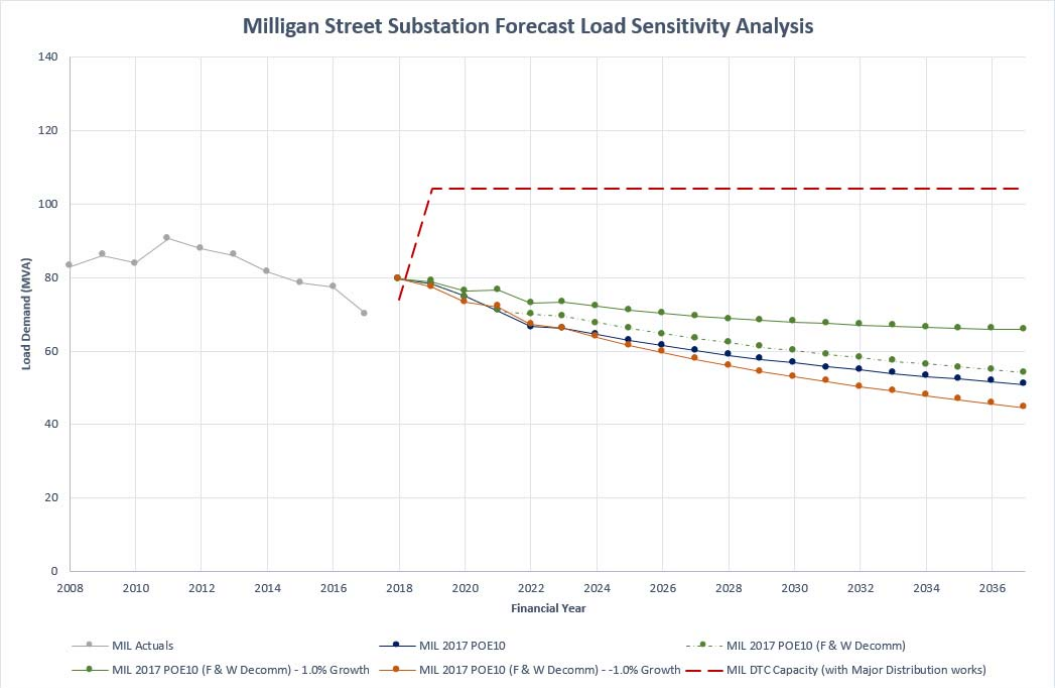

Figure 23: MIL Substation Forecast Load Sensitivity Analysis for Development Strategy 5

Appendix D: Key Assumptions

The following key assumptions have been used in the preparation of this Options Paper:

- The options assessment is based on the age and condition of the assets in the EP and CBD load area to determine their optimal investment strategies
- Western Power June 2017 load forecast has been utilised in the assessment of the investment options.
    - Demand growth sensitivity was based on ±1% in addition to the current load growth.
- The financial analysis utilised Western Power's Investment Evaluation Model. This model utilised the following parameters which were based on those agreed within Access Arrangement 3:
    - Weighted average cost of capital (WACC) of 6.53% is used as the discount rate (pre-tax nominal)
    - Annual escalation rates as:
        - 5.70% for labour
        - 2.45% for materials, equipment and plant
        - 2.50% for inflation
    - 2017/18 is used as the base year
    - The annualised impact on operating expenditure costs of new assets is calculated at 0.3% of capital expenditure (where applicable)
    - Cost sensitivity was based on ±20% on the capital expenditure across all investment options