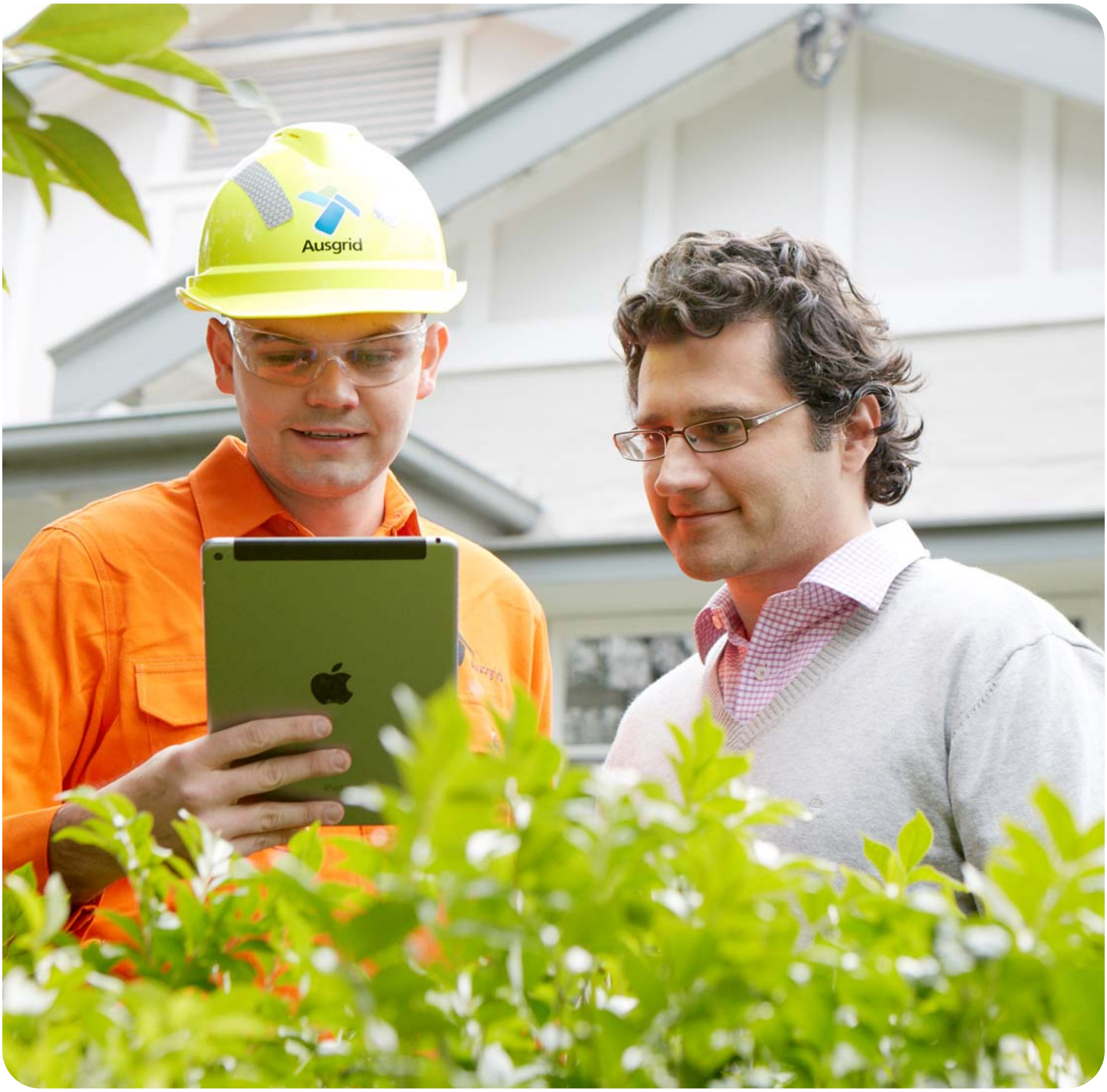
Ensuring reliability requirements in the Sydney CBD

Draft Project Assessment Report

19 April 2018



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Executive Summary

This report investigates the most economic option for continuing efficient supply to Sydney CBD

This Draft Project Assessment Report (DPAR) has been prepared by Ausgrid and represents the first step in the application of the Regulatory Investment Test for Distribution (RIT-D) to options for ensuring reliable electricity supply for Sydney CBD served by the existing City East and Dalley Street zone substations.

This RIT-D focusses on condition issues at the City East and Dalley Street zone substations, which if left unaddressed will increase the likelihood of equipment failure and lead to higher maintenance costs. The consequences of the equipment failure are primarily:

- loss of supply by customers (involuntary load shedding); and
- potential breaches of minimum feeder reliability standards that are part of Ausgrid's licencing conditions.

In responding to these drivers, consideration has also been given to the value of and opportunity to, minimise the risks of operating ageing oil filled equipment in close proximity to waterways.

Ausgrid considers that reliability correction action is required for the City East and Dalley Street zone substations to address the above needs. While replacing assets and refurbishing City East and Dalley Street zone substations is technically possible, Ausgrid considers that transferring existing loads to a nearby zone substation (Belmore Park), and then decommissioning the City East and Dalley Street zone substations, is more economically and technically efficient compared to replacing capital assets on a one-for-one basis.

Ausgrid has prepared this report in response to recent Rules changes requiring the RIT-D to be applied to replacement expenditure

Planning for a solution to address concerns at the City East and Dalley Street zone substations begun in early 2016, with staged plans being formulated for both zone substations. At the time, it was identified that there was a high degree of commonality in the task of transferring load away from each substation, in terms of building of pits and ducts along George, Bridge, Bond, Margaret, Pitt and College streets. The first stage of this plan commenced in 2016 to make the most of the limited window of opportunity for these works to occur given the construction of the CBD and South East Light Rail by the ALTRAC Light Rail consortium during this time.

Rule changes to the National Electricity Rules (NER) in July 2017 has meant that later stages of the project to address deteriorating and ageing assets at City East and Dalley Street zone substations are now subject to the Regulatory Investment Test for Distribution (RIT-D). Accordingly, Ausgrid has initiated this RIT-D for the remaining stages of the City East and Dalley Street zone substations projects in order to identify a preferred option that would ensure Ausgrid is able to satisfy its reliability and performance standards.

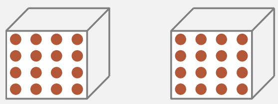
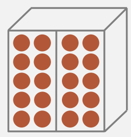
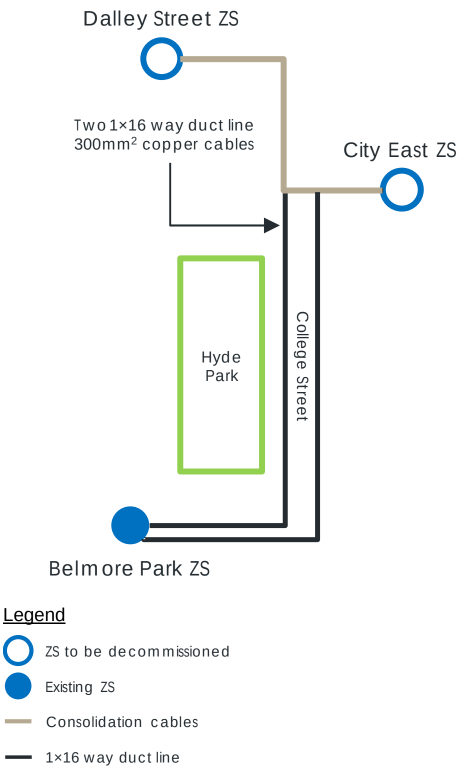
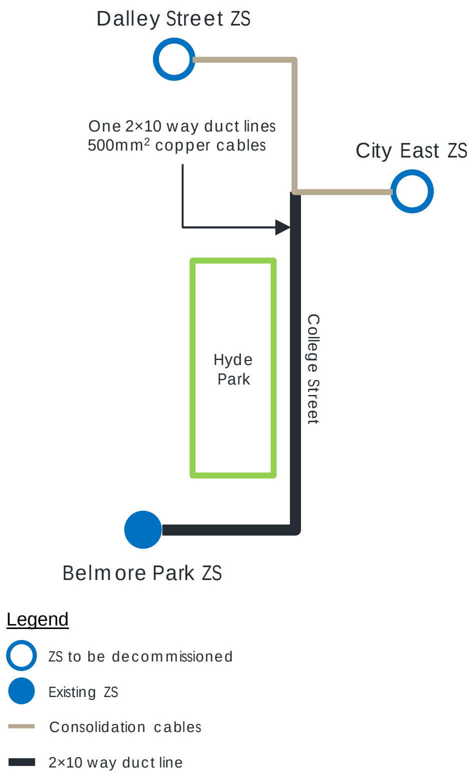
Ausgrid committed to initial stages of transferring approximately two thirds of the load at Dalley Street zone substation to the City North zone substation in 2016 prior to NER rule changes requiring replacement projects undergo a RIT-D process. Subsequent works to complete the transfer of the remaining load at Dalley Street zone substation and the load at City East zone substation are planned to occur between 2019 and 2025 and are the focus of this RIT-D.

Two credible network options have been assessed to address reliability concerns

The two options that have been assessed to address future reliability concerns are summarised in the table on the next page. The key difference between the two options is the type and capacity of duct banks that are to be installed along College Street, which runs the length of Hyde Park – namely:

- under Option 1, two 1×16 way duct banks are required along College Street – namely, two 1×16 way duct banks with 300mm^2 copper cables with the capacity to carry 40MVA each are installed on College Street, one on each side of the street, in order to fully transfer the 45MVA load at City East zone substation; while
- under Option 2, a single 2×10 way duct bank with 500 mm^2 copper cables is used – only one 2×10 way duct bank is required under this option because of its capacity to carry 90MVA compared to 40MVA for a 1×16 way duct bank.

Table 1 – Summary of the two credible options considered

Option details	Option 1	Option 2
Option description	Install two standard 1×16 way 11 duct banks with 300mm^2 copper cables along College Street. Consolidate loads at City East and Dalley Street zone substation then transfer the loads to the Belmore Park zone substation. Decommission City East and Dalley Street zone substations.	Install one 2×10 way duct banks with 500mm^2 copper cables along College Street. Consolidate loads at City East and Dalley Street zone substation then transfer the loads to the Belmore Park zone substation. Decommission City East and Dalley Street zone substations.
Total capacity	80MVA	90MVA
Capital cost ($m, 17/18)	$51.9 million	$40.6 million
Decommissioning costs	$3.4 million	$3.4 million
Duct bank(s) used along College Street	 Two 1x16 way duct banks (one on each side of College Street) with 300mm^2 copper cables – each with a 40MVA capacity	 One 2x10 way duct bank 500mm^2 copper cables (on one side of College Street) – a total of 90MVA capacity
High-level network diagram[1]	 	

[1] Diagrams presented in Table 1 are indicative only and are not to scale.

Non-network options are not considered viable for this RIT-D

Ausgrid has also considered the ability of any non-network solutions to assist in meeting the identified need. A demand management assessment into reducing the risk of unserved energy from the gaining zone substations showed that non-network alternatives cannot cost-effectively address the risk, compared to the two network options outlined above. This result is driven primarily by the significant amount of unserved energy that each network option allows to be avoided, compared to the base case, and is detailed further in the separate notice released in accordance with clause 5.17.4(d) of the NER.

If during the course of this RIT-D process, a cost-effective non-network solution emerges, then it will be assessed alongside the other options.

Three different 'scenarios' have been modelled to deal with uncertainity

Ausgrid has elected to assess three alternative future scenarios – namely:

- Low benefit scenario – Ausgrid has adopted several assumptions that give rise to a lower bound NPV estimate for each credible option, in order to represent a conservative future state of the world with respect to potential market benefits that could be realised under each credible option;
- Baseline scenario – the baseline scenario consists of assumptions that reflect Ausgrid's central set of variable estimates, which, in Ausgrid's opinion, provides the most likely scenario; and
- High benefit scenario – this scenario reflects an optimistic set of assumptions, which have been selected to investigate an upper bound on reasonably expected potential market benefits.

A summary of each scenario and the sets of variable values adopted is presented in Table 2 below.

Table 2 – Summary of the three scenarios investigated

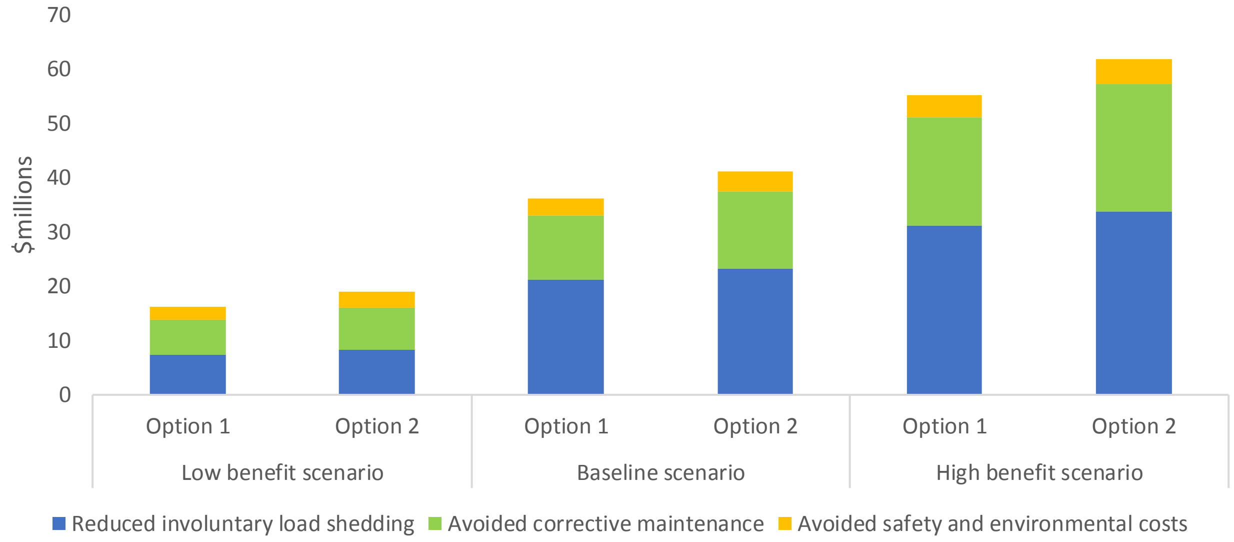
Variable	Baseline scenario	Low benefits scenario	High benefits scenario
Capital cost	100 per cent of baseline capital cost estimate	125 per cent of baseline capital cost estimate	75 per cent of baseline capital cost estimate
Unplanned corrective maintenance cost	100 per cent of baseline corrective maintenance cost estimates	70 per cent of baseline corrective maintenance cost estimates	130 per cent of baseline corrective maintenance cost estimates
Demand	POE50	POE90	POE10
VCR	$170/kWh	$90/kWh	$170/kWh
Discount rate	6.13 per cent	8.07 per cent	4.19 per cent

Option 2 has the highest expected net market benefits, under all scenarios

Expected benefits are driven primarily by reduced involuntary load shedding and avoided corrective maintenance that would otherwise be incurred under the base case.

Of the two options, Option 2 is found to have the highest net market benefit under all scenarios as its signficantly lower capital costs enable the option to be triggered earlier than Option 1 (ie, 2024/25 for Option 2 compared to 2026/27 for Option 1). This means that Option 2 has two additional years to accumulate benefits compared to Option 1. Option 2 also has a significantly lower cost than Option 1 (in the order or 20 per cent lower).

Figure 1 – Breakdown of gross benefits of each credible option relative to the base case, PV



The figure below provides a breakdown of costs relating to each credible option, in present value terms. The NPV of cost between the two options are similar under each scenario, however Option 2 has slighly lower costs in NPV terms. The slightly lower costs for Option 2 is driven by the fact that the type of duct bank used under this option only requires escavation on one side of College Street, which minimises excavation costs etc (as well as disruptions to the public, which have not been captured in this RIT-D assessment).

In absolute (ie, non-present value terms) the costs of Option 2 are approximatley 20 per cent lower than Option 1.

Figure 2 – Breakdown of gross costs of each credible option relative to the base case, PV

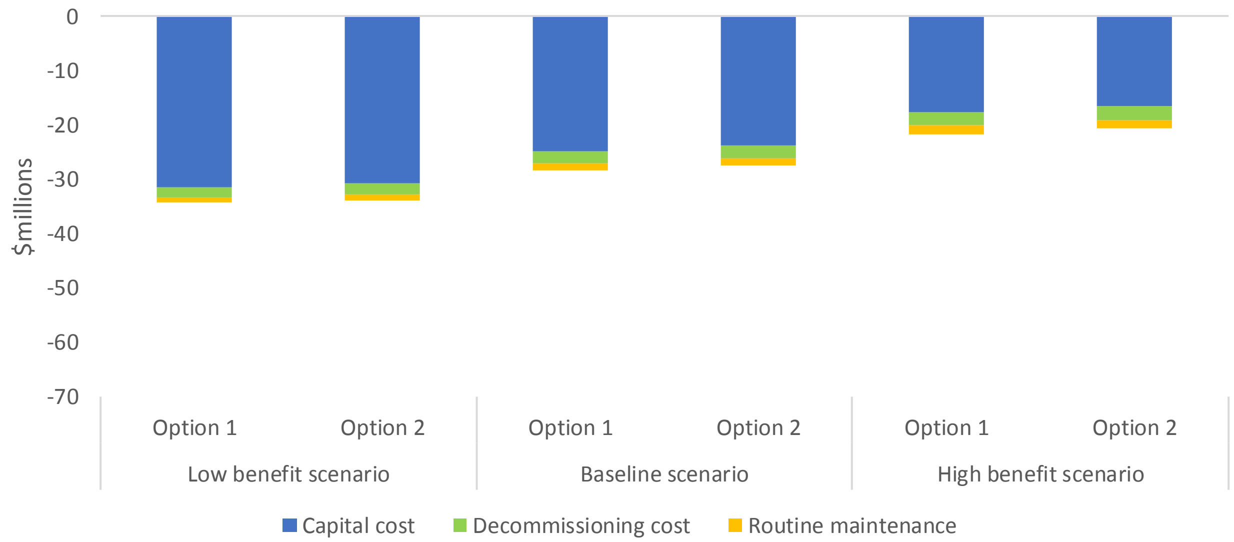


Table 3 below provides a summary of the net market benefit in NPV terms for each credible option, on a weighted basis across the three scenarios. Overall, Option 2 exhibits the highest estimated net market benefit, which is driven primarily by having lower capital costs that enable an earlier trigger year, which in turn allows Option 2 to generate two more additional years of avoided cost benefits compared to Option 1.

Table 3 – Present value of expected net benefits relative to the base case, $m 2017/18

Option	Capital costs	Operating costs	Weighted PV of gross benefits	Weighted NPV of benefits	Option ranking
Option 1	24.8	3.4	35.9	7.7	2
Option 2	**23.7**	**3.6**	**40.7**	**13.3**	**1**

Option 2 is the preferred option at this draft stage

Option 2 has been found to be the preferred option, which satisfies the RIT-D. It involves transferring the City East and Dalley Street substation loads to the Belmore Park zone substation in one 2×10 way duct bank and, subsequently, decommissioning the City East and Dalley Street substations. Ausgrid is the proponent for Option 2.

Option 2 offers the following benefits:

- it has significantly lower capital costs than Option 1 (i.e. it involves $41 million of capital cost compared to $52 million for Option 1);
- it involves excavating only one side of College Street to lay new cables (Option 1 requires both sides to be excavated);
- it provides greater network capacity than Option 1 (i.e. 90 MVA compared to 80 MVA);
- it addresses condition issues at both the City East and Dalley Street zone substations; and
- it involves less time to build than Option 1 and so causes less disruption to the community.[2]

In addition, both Option 1 and Option 2 have the significant benefit of being able to defer the likely build of a new zone substation in the CBD. In particular, if the City East and Dalley Street loads are not transferred to Belmore Park, then Ausgrid considers that a new zone substation would have to be constructed as soon as possible to cater for these loads. The estimated capital cost of such a substation is in the order of $155 million and so the avoidance of such a cost represents a significant benefit to both credible options. While noted, this benefit has not been estimated as part of this RIT-D since it would overwhelm the other benefits. Furthermore, the benefit from deferring the construction of a new zone substation is essentially the same magnitude for both credible options and therefore estimating would not assist in identifying the preferred option.

The scope of Option 2 includes:

- installing one 2×10-way duct bank with 500mm^2 copper cables on one side of College Street;
- measures to reduce the risk of duct bank common mode failure by altering the design of drop-in pits to limit the impact of a pit fire and having 500mm separation between banks;
- transfer of 11 kV load from the existing City East and Dalley Street zone substations to Belmore Park; and
- decommissioning of the existing City East and Dalley Street zone substations.

The estimated capital cost of Option 2 is $40.6 million with a further $3.4 million for decommissioning costs. Operating costs for Option 2 are assumed to be minimal given that it is expected new duct banks and feeders incur immaterial levels of maintenance over the 20 year period.

Ausgrid estimates that the environmental approval and construction timeline for Option 2 is 48 months, with commissioning of final stages expected during 2024/25. Final decommissioning of the existing zone substations and associated equipment at City East and Dalley Street is expected to be completed by 2025/26. Ausgrid intends to commence work on delivering Option 2 in 2018/19 (in particular, we intend to award the design and construction contract in July 2018, have environmental approvals finalised in August/September 2018 and to commence construction shortly after).

[2] For clarity, the benefit associated with lower community disruption has not explicitly been estimated, consistent with the RIT-D. However, Ausgrid considers this qualitative benefit is worth mentioning given the region of its network in question, i.e. Sydney CBD where any community disruption is likely to come at a high cost.

How to make a submission and next steps

Ausgrid welcomes written submissions on this DPAR. Submissions are due on or before 31 May 2018.

Submissions and queries should be addressed to:

Matthew Webb
Head of Asset Investment
Ausgrid
GPO Box 4009
Sydney 2001

Or

email to: assetinvestment@ausgrid.com.au

The next stage of this RIT-D involves publication of a Final Project Assessment Report (FPAR). The FPAR will update the quantitative assessment of the net benefit associated with different investment options, in light of any submissions received on this DPAR. Ausgrid intends to publish the FPAR as soon as practicable after submissions are received on this DPAR.

1 Introduction

The condition of ageing and legacy substation assets at the existing City East and Dalley Street zone substations have led to asset failures and malfunctions. As substation assets reach the end of their serviceable life, new failure modes are likely to appear and expose the CBD distribution network to increased risks of extended outages and other cost increases related to maintaining unsupported equipment in a safe and reliable state.

Ausgrid considers that reliability correction action is required for the City East and Dalley Street zone substations to comply with its electricity distribution license reliability and performance standards. While replacing and refurbishing City East and Dalley Street zone substations is technically possible, Ausgrid considers that transferring existing loads to a nearby zone substation (Belmore Park), and then decommissioning the City East and Dalley Street zone substations, is more economically and technically efficient compared to replacing capital assets on a one-for-one basis.

Planning for a solution to address concerns at the City East and Dalley Street zone substations begun in early 2016, with staged plans being formulated for both zone substations. At the time, it was identified that there was a high degree of commonality in the task of transferring load away from each substation, in terms of building of pits and ducts along George, Bridge, Bond, Margaret, Pitt and College streets. The first stage of this plan commenced in 2016 to make the most of the limited window of opportunity for these works to occur given the construction of the CBD and South East Light Rail by the ALTRAC Light Rail consortium during this time.

Rule changes to the National Electricity Rules (NER) in July 2017 has meant that later stages of the project to address deteriorating and ageing assets at City East and Dalley Street zone substations are now subject to the Regulatory Investment Test for Distribution (RIT-D). Accordingly, Ausgrid has initiated this RIT-D for the remaining stages of the City East and Dalley Street zone substations projects in order to identify a preferred option that would ensure Ausgrid is able to satisfy its reliability and performance standards.

Ausgrid committed to initial stages of transferring approximately two thirds of the load at Dalley Street zone substation to the City North zone substation in 2016 prior to NER rule changes requiring replacement projects undergo a RIT-D process. Subsequent works to complete the transfer of the remaining load at Dalley Street zone substation and the load at City East zone substation are planned to occur between 2019 and 2025 and are the focus of this RIT-D.

No exemptions listed in the NER clause 5.17.3(a) apply and therefore Ausgrid is required to apply the RIT-D to this project.

1.1 Role of this draft report

Ausgrid has prepared this Draft Project Assessment Report (DPAR) in accordance with the requirements of the National Electricity Rules (NER) under clause 5.17.4. It is the first stage of the formal consultation process set out in the NER in relation to the application of the RIT-D for this proposed project. In particular, this DPAR:

- describes the identified need which Ausgrid is seeking to address, together with the assumptions used in identifying this need;
- provides a description of each credible option assessed;
- quantifies costs and market benefits for each credible option;
- provides detailed description of the methodologies used in quantifying each class of cost and market benefit;
- explains why Ausgrid has determined that classes of market benefits or costs do not apply to a credible option;
- presents the results of a net present value analysis of each credible option and accompanying explanation of the results; and
- identifies and details information for the proposed preferred option.

A non-network options report has not been prepared as early stages of the project had been committed prior to the requirement to apply the RIT-D to asset replacement projects. However, non-network options were considered in formulating the plan to address issues at City East and Dalley Street zone substations and are described in section 3.3.

1.2 Making a submission and next steps

Ausgrid welcomes written submissions on this DPAR. Submissions are due on or before 31 May 2018.

Submissions and queries should be addressed to:

Matthew Webb
Head of Asset Investment
Ausgrid
GPO Box 4009
Sydney 2001

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email to: assetinvestment@ausgrid.com.au

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2 Description of the identifed need

This section provides a description of the network area and the 'identified need' for this RIT-D, before presenting a number of key assumptions underlying the identified need.

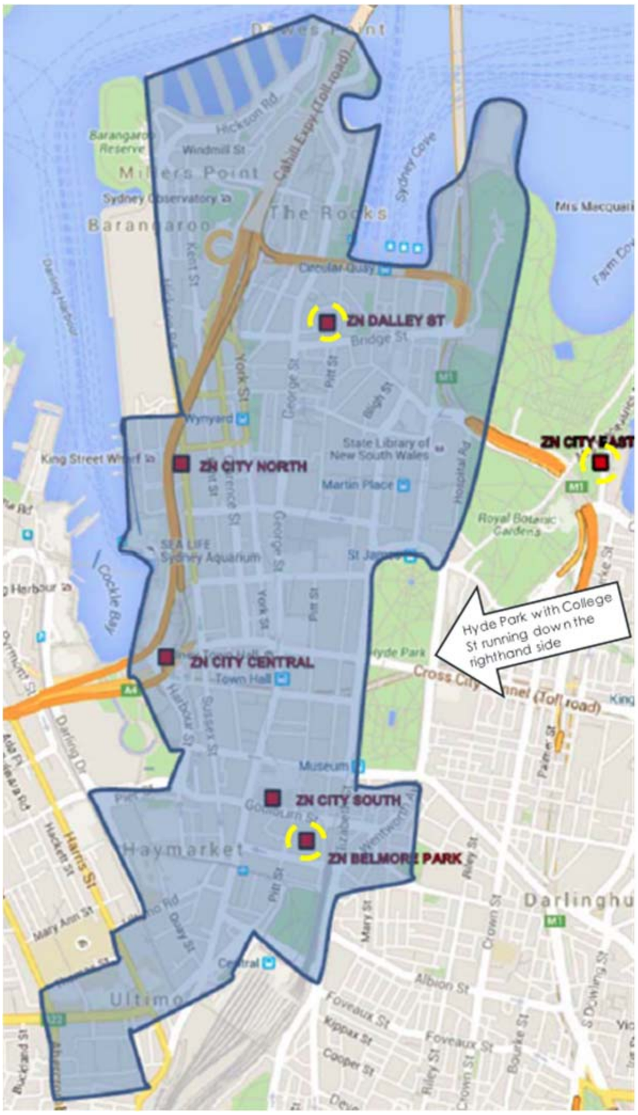
2.1 Overview of the Sydney CBD distribution network area

The Sydney CBD network area comprises an area of less than three square kilometres bounded by Barangaroo, Sydney Harbour, Darling Harbour, Central Railway Station and the Domain.

The distribution network serving the Sydney CBD is an 11kV network and extends from Circular Quay in the north, west to Darling Harbour, east to Woolloomooloo and south to Haymarket. The network in the CBD predominantly utilises an underground triplex construction.[3]

The figure below highlights the boundaries of the Sydney CBD network area and highlights the six zone substations (ZN) that service the area, which are discussed further below. The figure below also highlights the location of the three substations that are involved in the credible options outlined later in this DPAR (highlighted yellow), as well as the location of Hyde Park, which is also an important reference point for the options in this RIT-D.

Figure 3 – Map of the Sydney CBD network area



[3] The triplex design used on much of the distribution network in the CBD means distribution substations generally comprise of three distribution transformers supplied radially by three 11 kV feeders.

The Sydney CBD is the commercial heart of Sydney and contains a significant concentration of office buildings and apartments that all use substantial amounts of electricity. The peak demand for the Sydney CBD area is currently about 450MVA in the summer, where peak demand is predominately driven by air conditioning by customers.

The CBD area is served by six zone substations, five of which are located inside the CBD area and one (City East) that is located in the Royal Botanical Gardens next to Woolloomooloo. A summary of each substation is provided in Table 2.1 below.

Table 2.1 – Summary of the six zone substations currently serving Sydney CBD

Substation	Voltage (kV)	Planning capacity (n-2) MVA Summer	Planning capacity (n-2) MVA Winter	Summer limit	Winter limit
City East	33/11	63.2	72.8	33 kV underground feeder	33 kV underground feeder
Dalley Street	132/11	123.6	130	Transformer	Transformer
City North	132/11	167.9	167.9	Transformer	Transformer
City Central	132/11	128	130	Transformer	Transformer
City South	132/11	130.3	130.3	Transformer CT Differential	Transformer CT Differential
Belmore Park	132/11	128	130	Transformer	Transformer

These substations are supplied via TransGrid's Haymarket bulk supply point (BSP) and the Beaconsfield BSP, together with Ausgrid's Inner Metropolitan Transmission network that includes supply from Rozelle and Lane Cove STSS.

Ausgrid is currently in the process of transferring approximately two thirds of the existing Dalley Street zone substation load to the City North zone substation. This load transfer is expected to be completed by June 2020.

This RIT-D focusses on condition issues at the City East and Dalley Street zone substations, which if left unaddressed will increase the likelihood of equipment failure and lead to higher maintenance costs. The consequences of the equipment failure are primarily:

- loss of supply by customers (involuntary load shedding); and
- potential breaches of minimum feeder reliability standards that are part of Ausgrid's licencing conditions.

In responding to these drivers, consideration has also been given to the value of and opportunity to minimise the risks of operating ageing oil filled equipment in close proximity to waterways.

While the issues at City East and Dalley Street zone substations are independent of each other, Ausgrid considers that a solution for resolving each has a high degree of commonality. In particular, Ausgrid considers that the efficient solution involves transferring load away from each substation by way of new shared duct banks, pits and electricity distribution cables and eventually decommissioning of these substations. Consequently, Ausgrid has elected to consider solutions that combine City East and Dalley Street zone substation replacement projects together.

The two boxes on the next page provide an overview of each of these two substations and the condition of their assets.

Box 1 – Overview of the City East zone substation and the condition of assets

The City East zone substation located in the Royal Botanical Gardens was commissioned in 1964 and is the last 33/11kV substation serving the Sydney CBD area. Ausgrid has identified several issues at this zone substation, including:

- The 11 kV English Electric CV switchgear uses oil and bitumen insulated technology, which is unique in the Ausgrid network. This technology is obsolete and the lack of suitable spares for repairs and replacement means that in the event of a major failure the substation may remain switched off for an extended period, depending on the severity of the damage.
- The substation is also exposed to fire risk related to this technology in the event of a failure, both in terms of ignition risk and fire containment measures, with some risk of environmental pollution in the case of a major fire.

In addition, the distribution cable tunnel used for 11 kV feeders connecting the City East zone substation with the 11 kV network shows significant structural degradation. The tunnel was constructed in the early 1960s as a reinforced concrete box with asbestos sheeting used as formwork to support the concrete for the roof section. The most recent structural assessment of the tunnel identified degradation of the reinforced concrete roof in the original tunnel section, exposed asbestos sheeting, cracking of the gunite and concrete lining, water seepage, corrosion of steel cable brackets and other components within the tunnel. Ausgrid expects that the tunnel will continue to deteriorate as it ages and refurbishment will be required if the tunnel is to remain in service.

The 33 kV feeder cables supplying the City East zone substation are also ageing. Using paper/lead technology cables (HSL cable), they were mostly commissioned in 1964, while some sections are older and were commissioned in 1930. Unsurprisingly, older cables experience a higher number of failures. While paper/lead cables require less maintenance and are more easily repaired than gas pressure and oil filled cables, degradation of the paper insulation and lead sheath occurs due to ageing, moisture ingress through joints, 'through fault' currents and load cycling over their life. Accordingly, these cables will need replacement at some point in the future. The projected remaining life for the cables supplying City East zone substation is between 10 and 20 years.

Box 2 – Overview of the Dalley Street substation and the condition of assets

Half of the switchboards at the Dalley Street zone substation are made of a compound filled insulation type that has exhibited poor performance. This switchboard is ranked sixth worst out of 30 compound switchboard replacements required on the Ausgrid Network.

The other group of 11 kV switchboards are an air insulated type, which has experienced failure. In December 2014, a failure on one busbar of this switchgear occurred, caused by humidity, which created prolonged discharges between the busbar and the busbar barrier. In this instance, there was no consequent unserved energy on account of the 'triplex' redundancy in the system.

The December 2014 failure can be linked to ongoing degradation of the switchboard and highlights the potential for new failure modes to appear as the asset ages. In addition, the switchgear and circuit switch at the Dalley Street zone substation are also exhibiting signs of ageing, with SF_6 gas leaks[4] indicating these components are approaching the end of their serviceable life.

In addition, feeder cables supplying the Dalley Street zone substation use self-contained fluid filled (SCFF) cable technology, mostly installed in the 1960s and 1970s by the Electricity Commission of New South Wales and Sydney County Council. This type of cable requires fluid reservoirs, pressuring systems and pressure monitors to maintain the pressure within the cable to prevent cable failure. The maintenance requirements and costs for these SCFF cables are high compared to modern cross-linked polyethylene (XLPE) cables, primarily due to the need to keep the fluid systems in a serviceable condition. In addition to maintenance requirements for SCFF, unintended leakages from cable joints or deteriorated cable servings or sheaths present environmental risks.

Other secondary system components, including wall bushings, control and protection equipment, substation building and oil containment system are either approaching the end of their useful life or require some form of upgrade or remediation to maintain them in a serviceable condition.

[4] SF_6 refers to sulphur hexafluoride, which is a gaseous dielectric (i.e. insulator) for high voltage power applications.

2.2 Overview of Ausgrid's relevant statutory and regulatory obligations

Ausgrid is obliged to comply with reliability and performance standards as part of its distribution license granted by the Minister for Industry, Resources and Energy under the Electricity Supply Act 1995 (NSW). Under its license, reliability and performance standards are expressed in two measures:

- SAIDI[5] – which means the average derived from the sum of the durations of each sustained customer interruption (measured in minutes), divided by the total number of customers (averaged over the financial year); and
- SAIFI[6] – which means the average derived from the total number of sustained customer interruptions divided by the total number of customers (averaged over the financial year).

These two reliability measures capture two key sources of inconvenience to electricity customers from supply disruptions, i.e. how long their electricity supply is off for as well as how often their electricity supply is off. Customers experience less inconvenience (i.e. a better level of supply reliability), the lower each of these measures are. Reliability standards applied to distribution networks typically set maximums in relation to each of these two measures.

Table 2.2 sets out the reliability standards that currently apply to Sydney CBD.

Table 2.2 – Sydney CBD reliability standards

Feeder type	SAIDI (minutes per customer)	SAIFI (number per customer)
Network overall reliability standards	45	0.3
Individual feeder standards	100	1.4

2.3 Key assumptions underpinning the identified need

The need to undertake action is predicated on the deteriorating condition of assets at the existing City East and Dalley Street zone substations, and the characteristics of any resultant outages, as well as the fact that maintaining technologies present heightened maintenance and asset failure risks.

This section summarises the key assumptions underpinning the identified need for this RIT-D. Appendix C provides additional detail on assumptions used, and methodologies applied, to estimate the costs and market benefits as part of this RIT-D.

2.3.1 Ageing assets at the each zone substation have an increasing liklihood of failure

Several network assets located at or connected to City East and Dalley Street are ageing legacy assets and are showing signs of deterioration. Continued use of these assets is expected to increase the risk of involuntary load shedding going forward, corrective maintenance costs and safety/environmental costs.

Notable assets in this condition include:

- Feeders at the City East zone substation
  - The 33 kV feeder cables connected to the City East zone substation were mostly commissioned in 1964 (currently 51 years old), but there are sections on feeders 507 and 508 that were commissioned in 1946 (currently 69 years old) and some on section 509 that were commissioned in 1930 (currently 85 years old).
  - These cables have standard technical lives of 60 years and, unsurprisingly, older cables have a higher number of failures and are predominantly those on which recent failures have occurred.
- Distribution cable tunnel at City East zone substation
  - The existing tunnels were constructed in two stages with the original tunnel section constructed in 1960 (90 metres) and an extension undertaken in 1963 (150 metres).
  - The original tunnel section was constructed as a reinforced concrete box section with asbestos sheeting used as formwork to support the concrete for the roof section when it was poured. Defects identified during inspections included degradation of the reinforced concrete roof in the original tunnel

[5] System Average Interruption Duration Index.
[6] System Average Interruption Frequency Index.

section, exposed asbestos sheeting, cracking of the Gunite and concrete lining, water seepage and corrosion of steel cable brackets and other components within the tunnel.

- 132 kV gas insulated switchgear and circuit switches at the Dalley Street zone substation
  - Switchgear at Dalley Street have experienced SF_6 gas leaks,[4] which indicates that they are reaching the end of their serviceable life.
  - Furthermore, the Reyrolle LMT switchgear has experienced failure as recently as December 2014, where humidity and the air-gap clearances between the busbar and the barrier caused a partial discharge at the K busbar. The failure highlights the potential for new failure modes to appear as assets age and approaches the end of their useful life.

Appendix C presents technical detail on the engineering assumptions and methodologies that have been used to model the availability of these assets going forward and the consequences for expected involuntary load shedding, corrective maintenance costs and safety/environmental costs.

2.3.2 Legacy technologies add to expected maintenance costs and asset failure risks

City East and Dalley Street zone substations make use of legacy technologies that increases the cost of maintenance and heightens environmental risk and can potentially prevent Ausgrid from undertaking replacements in the event of asset failures.

Notable legacy technologies used at City East and Dalley Street zone substations include:

- Switchgear and circuit breakers at City East zone substation
  - These network assets utilise compound insulated switchboards with oil filled circuit breakers. This technology is unique in the Ausgrid network and is no longer supported by suppliers.
  - Consequently, there is a lack spares to undertake unit replacement. In the event of failure, there is a risk that the substation maybe left switched for an abnormally extended period of time.
- Switchgear at the Dalley Street zone substation
  - Dalley Street zone substation contains both compound insulated Email HQ and air insulated Reyrolle LMT types of 11 kV switchgear.
  - The Email HQ switchgear was last tested in 2004 and results did not indicate any action was required at the time. However, Ausgrid has experience an explosive failure of this type of switchgear at Dulwich Hill in 2012 that compromised the structural integrity of the substation building.
- 132 kV oil feeders at the Dalley Street zone substation
  - Feeders into the Dalley Street zone substation employ self-contained fluid filled (SCFF) cable technology that were installed in the 1960s and 1970s.
  - These cables are more expensive to maintain compared to more modern cable technologies due to maintain fluid pressure. Additionally, synthetic oils are used as fluid in SCFF, which presents environmental risk where fluid leakages occur.

These legacy technologies present Ausgrid with operational risks related to the ability to undertake corrective maintenance, and environmental risks from fluid leakages into the environment.

2.3.3 City East zone substation pollution risk following an incident

While not the key driver for the project, in the event of a major fire and oil leak at City East zone substation, there is a risk of pollution to the surrounding area and/or waterways. Pollution of waterways in particular, would be an offence under the *Protection of Environment Operations Act 1997* for pollution of waters, which carries heavy penalties.

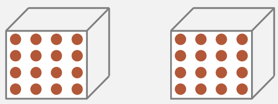
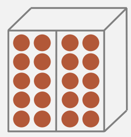
Appendix C outlines the facts and assumptions Ausgrid has used to estimate this cost (which is avoided under both credible options once City East is decommissioned).

3 Two credible options have been assessed

This section provides descriptions of the credible options Ausgrid identified as part of its network planning activities to date. In particular, Ausgrid has identified two network options that involve transferring the load from the existing City East and Dalley Street zone substations elsewhere in the distribution network and decommissioning both of these substations.

The two credible options are summarised in the table below. All costs are in $2017/18, unless otherwise stated.

Table 3.1 – Summary of the credible options considered

Option details	Option 1	Option 2
Option description	Install two standard duct banks with $300mm^2$ copper cables along College Street. Consolidate loads at City East and Dalley Street zone substation then transfer the loads to the Belmore Park zone substation. Decommission City East and Dalley Street zone substations.	Install one 2×10 way duct banks with $500mm^2$ copper cables along College Street. Consolidate loads at City East and Dalley Street zone substation then transfer the loads to the Belmore Park zone substation. Decommission City East and Dalley Street zone substations.
Total capacity	80MVA	90MVA
Capital costs	$51.9 million	$40.6 million
Decommissioning costs	$3.4 million	$3.4 million
Duct bank(s) used along College Street	 Two 1x16 way duct banks (one on each side of College Street) – each with a 40MVA capacity	 One 2x10 way duct bank (on one side of College Street) – a total of 90MVA capacity

The key difference between Option 1 and Option 2 is the type and capacity of duct banks that are to be installed along College Street, which runs the length of Hyde Park – namely:

- under Option 1, two 1×16 way duct banks are required along College Street – namely, two 1×16 way duct banks with $300mm^2$ copper cables with the capacity to carry 40MVA each are installed on College Street, one on each side of the street, in order to fully transfer the 45MVA load at City East zone substation; while
- under Option 2, a single 2×10 way duct bank with $500mm^2$ copper cables is used – only one 2×10 way duct bank is required because of its capacity to carry 90MVA compared to 40MVA for a 1×16 way duct bank.

Both credible options have the significant benefit of being able to defer the likely build of a new zone substation in the CBD. In particular, if the City East and Dalley Street loads are not transferred to Belmore Park, then Ausgrid considers that a new zone substation would have to be constructed as soon as possible to cater for these loads. The estimated capital cost of such a substation is in the order of $155 million and so the avoidance of such a cost represents a significant benefit to both credible options.[7]

[7] While both Option 1 and Option 2 will defer the need for a new zone substation in the northern part of the CBD, Ausgrid has elected to not capture the determent benefit as the difference between capital costs that would occur in the base case, and those for Option 1 and Option 2. The reason for this is that this benefit overwhelms the other benefits (since it is around $155m of capital cost being deferred) and is essentially the same for each option (since they both avoid this expenditure) and therefore does not assist in identifying a preferred option.

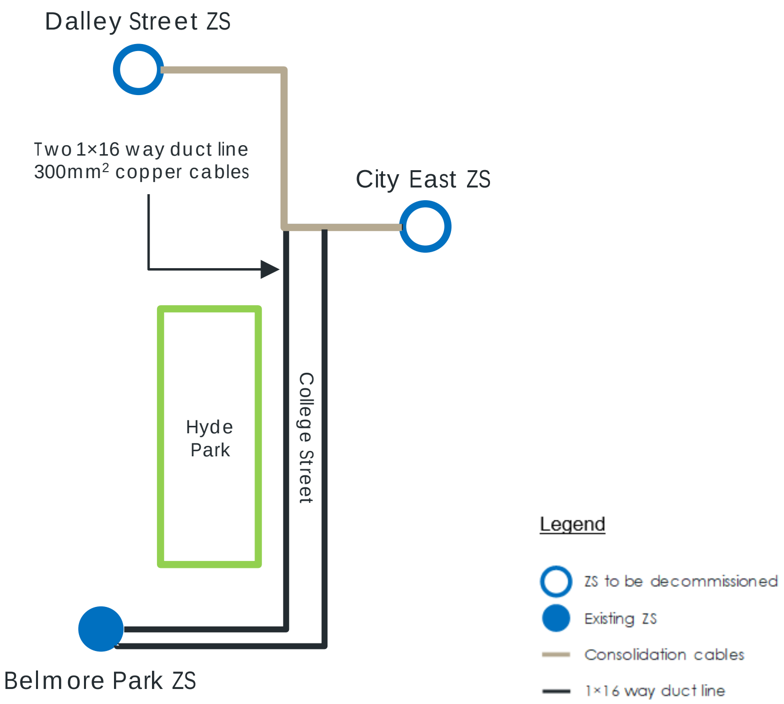
Ausgrid has also considered a number of different options, including refurbishment of the existing substations and building a new zone substation, but has deemed these not credible and consequently not progressed these options. These options considered but not progressed are discussed in section 3.4 below.

Ausgrid has also determined that non-network solutions are unlikely to form a standalone credible option, or form a significant part of a potential credible option, as set out in the separate notice released in accordance with clause 5.17.4(d) of the NER. A summary of Ausgrid's consideration of non-network options is provided in section 3.4 below.

3.1 Option 1 – Transfer City East and Dalley Street substation loads to Belmore Park zone substation on two standard 1×16 way duct banks

Option 1 involves transferring load from the City East and Dalley Street zone substations to Belmore Park zone substation. Once the load is transferred, City East and Dalley Street zone substations can be decommissioned.

Figure 4 – High-level network diagram for Option 1



This option requires extensive duct construction through the CBD streets. In particular, the connection to the Belmore Park zone substation requires a 1×16 way duct bank with 300mm^2 copper cables along each side of College Street, since each side can only accommodate one new duct bank. Two 1×16 way duct banks are required in order to provide sufficient total capacity to transfer both City East (45MVA) and Dalley Street (25MVA) zone substation load. Each 1×16 way duct bank costs approximately $16 million and has a capacity of approximately 40 MVA, noting that such capacity is not adequate to accommodate expected loads by 2030. This option also involves a further $12 million in circuit reconfiguration, jointing and termination works, as well as staged commissioning of the new 11kV feeders.

The estimated capital cost of this option is approximately $51.9 million, while decommissioning cost of City East and Dalley Street zone substations is estimated to be $3.4 million. A summary of capital costs is set out in Table 3.2. Option 1 would commence in 2020/21 and progress in stages until construction is completed in 2025/26, and the last stage of new 11kV feeders commissioned in 2026/27.

Table 3.2 – Main capital components under Option 1, $millions

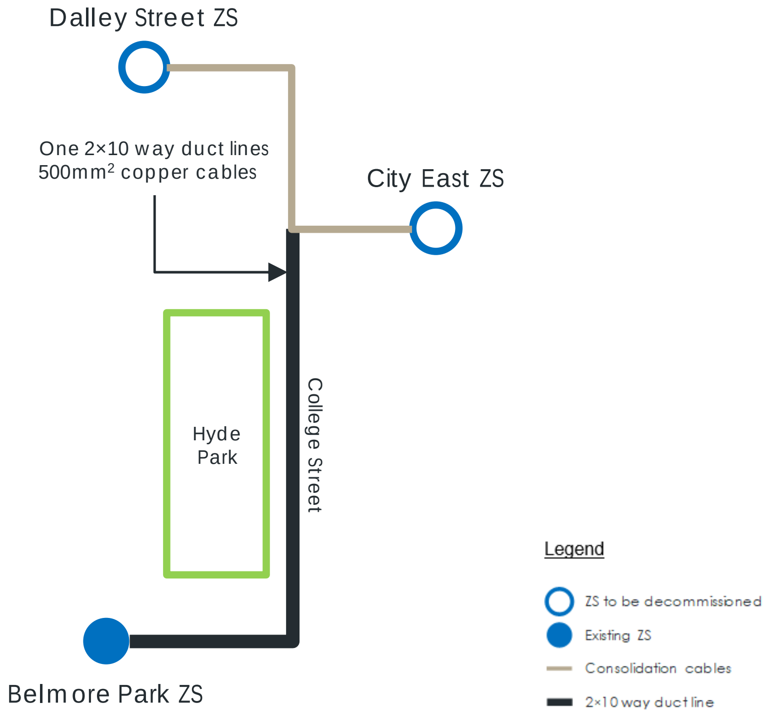
Main component	Capital cost
City East zone substation transfer and College Street duct banks	44.2
Dalley Street zone substation transfers	7.7
Total capital costs	**51.9**

3.2 Option 2 – Transfer City East and Dalley Street substation loads to Belmore Park zone substation on one 2×10 way duct lines

Option 2 involves the same route as Option 1 but uses one 2×10-way duct bank with 500mm^2 copper cables that requires only one side of College Street to be excavated.

By using high capacity cables and adequate spacing between ducts, up to 90MVA can be transferred, which is sufficient to offload both City East and Dalley Street zone substations and accommodate expected load growth in these network areas up to 2030. This option includes measures to reduce the risk of duct bank common mode failure by altering the design of drop-in pits to limit the impact of a pit fire and 500mm separation between banks.

Figure 5 – High-level network diagram for Option 2



The capital cost of this option estimated to be $40.6 million, while decommissioning costs of City East and Dalley Street zone substations are estimated to be $3.4 million. The capital cost includes the cost of the 2x10-way duct bank, which is approximately $21 million, and the cost of circuit reconfiguration, termination and staged commissioning, which is approximately $12 million. A summary of capital costs is set out in the table below. Option 2 would commence in 2018/19 and occur in stages, with construction completed in 2023/24 and the last stage of new 11kV feeders commissioned in 2024/25.

Table 3.3 – Main capital components under Option 2, $millions

Main component	Capital cost
City East zone substation transfer and College Street duct banks	32.9
Dalley Street zone substation transfers	7.7
Total capital costs	**40.6**

3.3 Options considered but not progressed

Ausgrid also considered several other options that have not been progressed. In general, these options were not progressed because they were found to be technically infeasible, economically infeasible, or they are materially similar to options considered above.

The table below summarises Ausgrid's consideration and position on each of these potential options.

Table 3.4 – Options considered but not progressed

Option not progressed	Description	Reason why option was not progressed
Establish a new zone substation in the northern region of the CBD (likely between City East and Dalley Street)	This option would involve establishing a new zone substation in the northern region of the CBD and the transfer of City East and Dalley Street loads there.	Preliminary analysis found that this option was significantly costlier than the two credible options (around $155m), without providing any additional market benefits. It was therefore deemed that this option was not economically credible.
Refurbishment of City East zone substation to serve loads at City East and Dalley Street zone substations.	This option would involve temporarily transferring City East and Dalley Street zone substation loads to Belmore Park, refurbishing the City East zone substation, then transferring load back to City East and decommissioning Dalley Street zone substation.	Ausgrid estimates that this option would cost around $115 million, which is significantly higher than the credible options considered without commensurate levels of market benefits. It was therefore deemed that this option was not economically credible.
Refurbishment of both City East and Dalley Street zone substations.	This option would involve temporality transferring City East and Dalley Street zone substation loads to Belmore Park zone substation, undertake refurbishment and replacement works at each respective zone substation, then transferring load back to City East and Dalley Street zone substations.	Ausgrid estimates that this option would cost more than the $115 million estimated for just a City East refurbishment, which is significantly higher than the credible options considered without commensurate levels of market benefits. It was therefore deemed that this option was not economically credible.

In addition to the options considered but not progressed set out in the table above, Ausgrid considered but ruled out a load transfer route along Elizabeth Street as access is restricted until after 2019. Specifically, Elizabeth Street is currently being used as an alternate transport route to George Street while the light rail network is installed along George Street.

Ausgrid also considered non-network options more generally. Demand management has the potential to mitigate or address the risk of unserved energy due to equipment failure leading to load shedding, but cannot address the risk of unserved energy from multiple, coincident failures leading to a total loss of connectivity, or the non-energy risks. As only a small portion of the unserved energy risk is associated with failure modes leading to load shedding, it is not considered that demand management can contribute in any material way to a viable solution to the identified need.

If during the course of this RIT-D process, a cost-effective non-network solution emerges, then it will be assessed alongside the other options.

4 How the options have been assessed

This section outlines the methodology that Ausgrid has applied in assessing market benefits and costs associated with each of the credible options considered in this RIT-D. Appendix C presents additional detail on the assumptions and methodologies employed to assess the two credible options.

4.1 General overview of the assessment framework

All costs and benefits for each credible option have been measured against a 'business as usual' base case. Under this base case, Ausgrid is assumed to undertake escalating regular and reactive maintenance activities as the probability of failure and outages increases over time in the absence of an asset replacement program.

The RIT-D analysis has been undertaken over a 20 year period, from 2017/18 to 2036/37. Ausgrid considers that a 20 year period takes into account the size, complexity and expected life of the relevant credible options to provide a reasonable indication of the market benefits and costs of the options. While the capital components of the credible options have asset lives greater than 20 years, Ausgrid has taken a terminal value approach to incorporating capital costs in the assessment, which ensures that the capital cost of long-lived options is appropriately captured in the 20 year assessment period.

Ausgrid has adopted a central real, pre-tax discount rate of 6.13 per cent as the central assumption for the NPV analysis presented in this report. Ausgrid considers that this is a reasonable contemporary approximation of a 'commercial' discount rate (a different concept to a regulatory WACC), consistent with the RIT-D.[8]

Ausgrid has also tested the sensitivity of the results to changes in this discount rate assumption, and specifically to the adoption of a lower bound real, pre-tax discount rate of 4.19 per cent (equal to the latest AER Final Decision for a DNSP's regulatory proposal at the time of preparing this DPAR[9]), and an upper bound discount rate of 8.07 per cent (i.e., a symmetrical upwards adjustment).

4.2 Ausgrid's approach to estimating project costs

Ausgrid has estimated capital costs by considering the scope of works necessary under each credible option together with costing experience from previous projects of a similar nature. Where possible, Ausgrid has also estimated capital costs for each credible option using supplier quotes or other pricing information.

Operating and maintenance costs have been determined for each option by comparing the operating and maintenance costs with the option in place to the operating and maintenance costs without the option in place. These costs are included for each year in the planning period. If operating and maintenance costs are reduced with an option in place, the cost savings are effectively treated as a benefit in the assessment.

Operating costs have been estimated for each credible option and the base case by considering:

- the probability and expected level of network asset faults, which translates to the level of corrective maintenance costs; and
- the level of regular maintenance required to maintain network assets in good working order, including planned refurbishment costs.

All options reduce the incidence of asset failures earlier than the base case, and hence the expected unplanned corrective maintenance costs associated with restoring supply.

Ausgrid has also included the financial costs associated with safety and environmental outcomes that are assumed to be avoided under each of the options, relative to the base case. These costs have been estimated using internal Ausgrid estimates, and are found to be immaterial in the analysis, both in terms of absolute values as well as being the same across the two credible options considered.

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[8] Ausgrid notes that it has been sourced from the discount rate recently independently estimated as part of the Powering Sydney's Future RIT-T. See: TransGrid and Ausgrid, *Project Assessment Conclusions Report*, Powering Sydney's Future, November 2017, p. 62 – available at: https://www.transgrid.com.au/news-views/lets-connect/consultations/current-consultations/Documents/Powering%20Sydney%27s%20Future%20-%20PACR.pdf

[9] See TasNetworks' PTRM for the 2017-19 period, available at: https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/tasnetworks-determination-2017-2019/final-decision

4.3 Benefits are expected from both reduced involuntary load shedding, as well as lower operating costs

Ausgrid considers that the only relevant category of market benefits prescribed under the NER for this RIT-D relate to changes in involuntary load shedding. Appendix D outlines the categories of market benefit that Ausgrid considers are not material for this particular RIT-D.

Involuntary load shedding is where a customer's load is interrupted from the network without their agreement or prior warning. Ausgrid has forecast load over the assessment period and has quantified the expected unserved energy by comparing forecast load to network capabilities under system normal and network outage conditions. A reduction in involuntary load shedding expected from an option, relative to the base case, results in a positive contribution to market benefits of the credible option being assessed.

Involuntary load shedding of a credible option is derived by the quantity in MWh of involuntary load shedding required assuming the credible option is completed multiplied by the Value of Customer Reliability (VCR). The VCR is measured in dollars per MWh and is used as proxy to evaluate the economic impact of unserved energy on customers under the RIT-D.

Ausgrid has applied a central VCR estimate of $170/kWh based on the mid-point of a range estimate of VCR for the Sydney CBD by HoustonKemp in 2017[10] . This value considers that the $90/kWh VCR estimate proposed in the recent Independent Pricing and Regulatory Tribunal (IPART) review of the transmission reliability standards is an average for the Inner Sydney area, with lower VCR estimates for several sub-sections of the network area – such as $40/kWh which we have used for Canterbury-Bankstown, Inner West or Lower North Shore- and higher VCR estimates for Sydney CBD. This approach recognises that there is higher-than average economic output produced by the CBD customers supplied from City East and Dalley St zone substations

We have also investigated the effect of assuming both a lower underlying VCR estimate. The lower sensitivity is based on the $90/kWh VCR estimate for Inner Sydney, consistent with the recent IPART review of the transmission reliability standards for Inner Sydney, as well as the recently finalised Powering Sydney's Future RIT-T.[11]

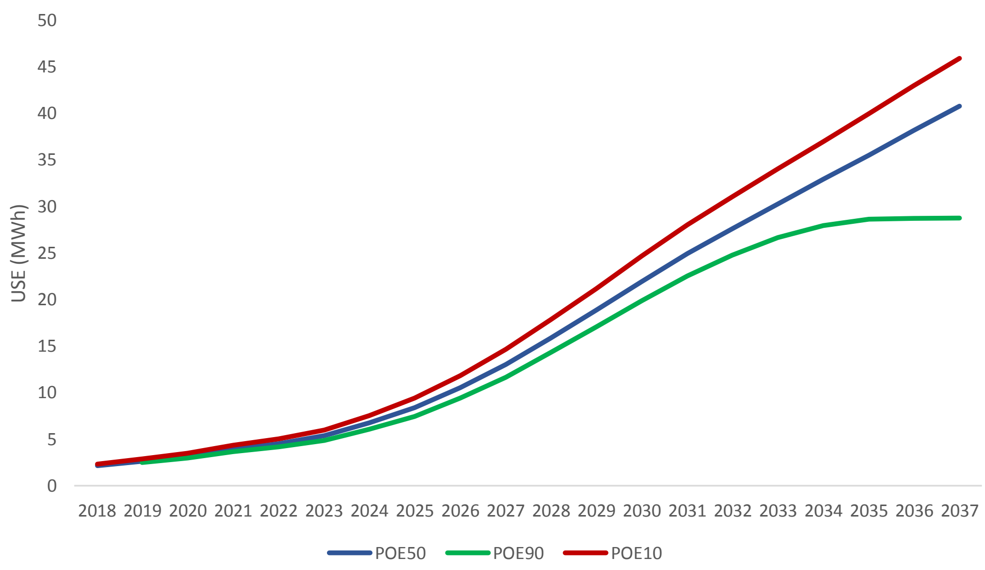
In addition, while load forecasts are not a determinant of the identified need (since the reliability standards expected to be breached relate to the *duration* and *frequency* of supply interruptions – neither of which are affected by underlying load), Ausgrid has investigated how assuming different load forecasts going forward changes the expected net market benefits under the options. In particular, we have investigated three future load forecasts for the area in question – namely a central forecast using our 50 per cent probability of exceedance ('POE50') forecasts, as well as a low forecast using the POE90 forecasts and a high forecast using the POE10 forecasts.

The figure below shows the assumed levels of unserved energy, under each of the three underlying demand forecasts investigated over the next ten years. For clarity, this figure illustrates the MWh of unserved energy assumed under each load forecast, if neither of the two credible options is commissioned.

[10] HoustonKemp, *CBD and Inner Metro VCR estimates*, 28 July 2016, p. 2.

[11] TransGrid and Ausgrid, *Project Assessment Conclusions Report*, Powering Sydney's Future, November 2017 – available at: https://www.transgrid.com.au/news-views/lets-connect/consultations/current-consultations/Documents/Powering%20Sydney%27s%20Future%20-%20PACR.pdf

Figure 6 – Assumed level of USE under each of the three demand forecasts



Ausgrid has elected to adopt a conservative estimate for POE90 (ie low USE) where it is assumed that growth in demand levels off in later years that reflects increases in efficiency and limited growth.

4.4 Three different 'scenarios' have been modelled to address uncertainity

RIT-D assessments are required to be based on cost-benefit analysis that includes an assessment of 'reasonable scenarios', which are designed to test alternate sets of key assumptions and whether they affect identification of the preferred option.

Ausgrid has elected to assess three alternative future scenarios – namely:

- Baseline scenario – the baseline scenario consists of assumptions that reflect Ausgrid's central set of variable estimates, which, in Ausgrid's opinion, provides the most likely scenario;
- Low benefit scenario – Ausgrid has adopted a number of assumptions that give rise to a lower bound NPV estimate for each credible option, in order to represent a conservative future state of the world with respect to potential market benefits that could be realised under each credible option; and
- High benefit scenario – this scenario reflects an optimistic set of assumptions, which have been selected to investigate an upper bound on reasonably expected potential market benefits.

Table 4.1 – Summary of the three scenarios investigated

Variable	Baseline scenario	Low benefits scenario	High benefits scenario
Capital cost	100 per cent of capital cost estimate	125 per cent of capital cost estimate	75 per cent of capital cost estimate
Unplanned corrective maintenance cost	100 per cent of baseline corrective maintenance cost estimates	70 per cent of baseline corrective maintenance cost estimates	130 per cent of baseline corrective maintenance cost estimates
Demand	POE50	POE90	POE10
VCR	$170/kWh	$90/kWh	$170/kWh
Discount rate	6.13 per cent	8.07 per cent	4.19 per cent

Ausgrid considers that the baseline scenario is the most likely, since it based primarily on a set of expected/central assumptions. Ausgrid has therefore assigned this scenario a weighting of 50 per cent, with the other two scenarios being weighted equally with 25 per cent each. However, Ausgrid notes that the identification of the preferred option is the same across all three scenarios, i.e. the result is insensitive to the assumed scenario weights.

5 Assessment of credible options

This section provides a description of four credible network options Ausgrid has identified as part of its network planning activities to date. All credible options assessed as part of this RIT-D will be compared against a base case 'do nothing' option.

5.1 Gross market benefits for each credible option

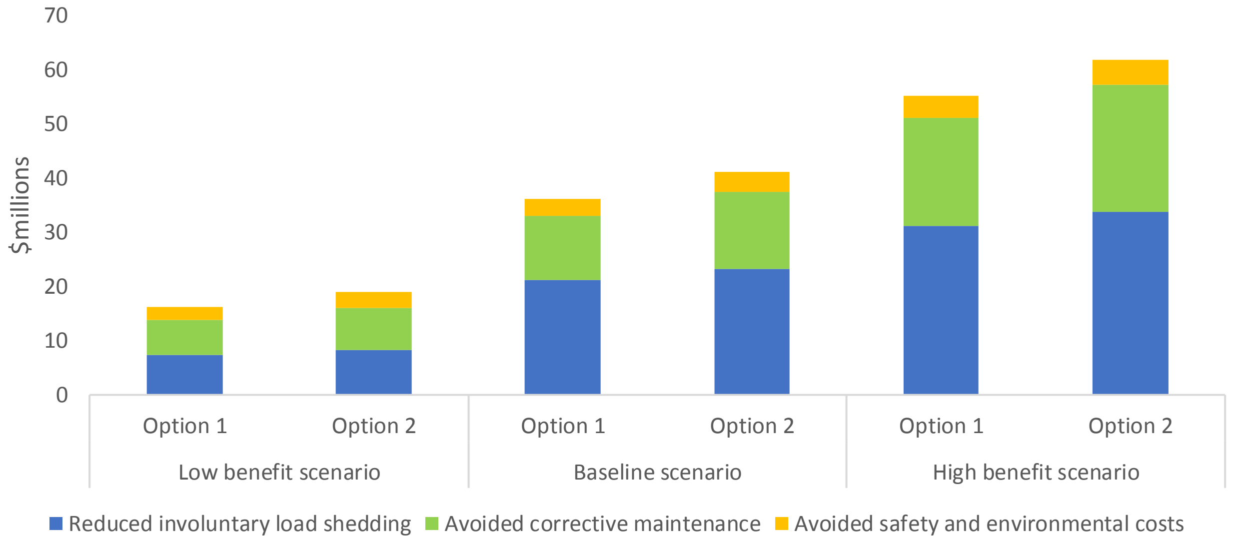
The table below summarises the gross benefit of each credible option relative to the base case in present value terms. The gross market benefit for each option has been calculated for each of the three reasonable scenarios outlined in the section above.

Table 5.1 – Present value of gross benefits of relative to the base case, $m 2017/18

Option	Scenario 1	Scenario 2	Scenario 3	Weighted benefits
Weighting	*25 per cent*	*50 per cent*	*25 per cent*	–
Option 1	16.2	36.1	55.0	35.9
Option 2	19.0	41.0	61.7	40.7

Figure 7 provides a breakdown of benefits relating to each credible option, showing most economic benefits from Option 1 and Option 2 are derived from reduced involuntary load shedding and avoided corrective maintenance, with avoided safety and environmental benefits contributing relatively small amounts to gross benefits.

Figure 7 – Breakdown of present value gross economic benefits of each credible option relative to the base case



Gross benefits under Option 2 are higher than Option 1 under all scenarios as Option 2 is triggered earlier than Option 1 (Option 1 in 2026/27 and Option 2 in 2024/25 as reported in Section 5.4.1). This allows Option 2 to generate two more years of avoided cost benefits compared to Option 1.

5.2 Estimated costs for each credible option

The table below summarises the gross costs of each credible option relative to the base case in present value terms. The gross cost is the sum of the project capital costs, operating costs and decommissioning costs.

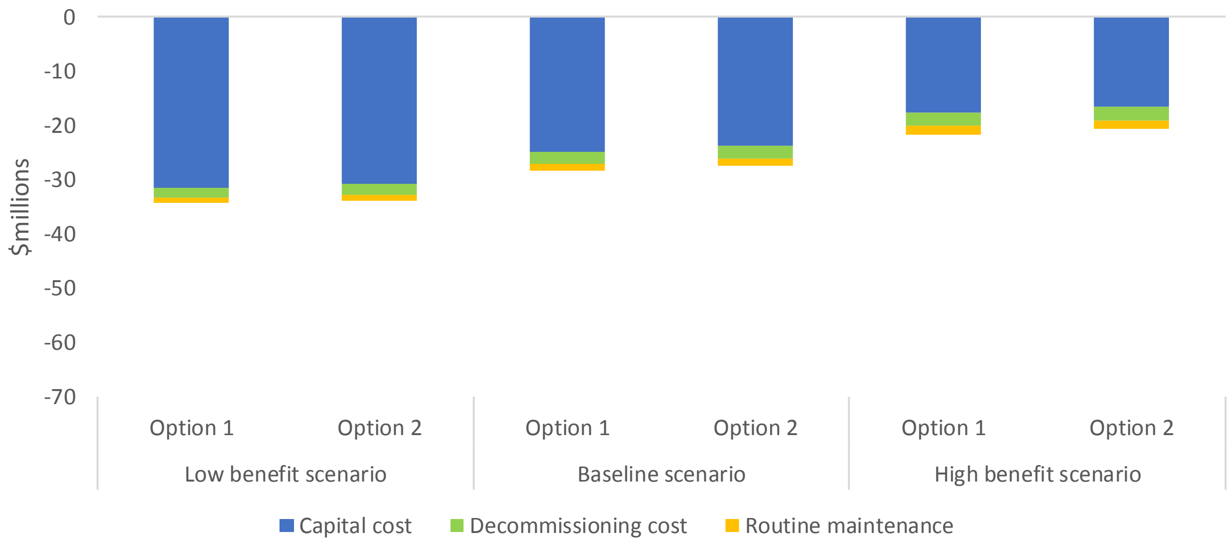
The gross cost of each option has been calculated for each of the three reasonable scenarios, in accordance with the approaches set out in Section 4.

Table 5.2 – Present value of gross costs of each credible option relative to the base case, $m 2017/18

Option	Scenario 1	Scenario 2	Scenario 3	Weighted costs
Weighting	*25 per cent*	*50 per cent*	*25 per cent*	–
Option 1	-34.3	-28.3	-21.7	-28.1
Option 2	-33.8	-27.4	-20.7	-27.3

Figure 8 provides a breakdown of costs for City East and Dalley Street zone substations for each credible option, showing the present value of costs between Option 1 and Option 2 is very similar. The Capital cost for Option 1 is only $0.9 million higher in present value terms under the baseline scenario than Option 2 in present value terms even though the difference in undiscounted $2017/18 terms is equal to $11.3 million. This is caused by the fact that Option 1 has a longer construction/commissioning timeframe than Option 2, which results in higher discounted factors applied to project cashflows in Option 1. In absolute terms (i.e. non-present value terms) the costs of Option 2 are approximatley 20 per cent lower than Option 1. As noted in section 5.1, Option 1 also has delayed benefits relative to Option 2.

Figure 8 – Breakdown of present value gross costs of each credible option relative to the base case



5.3 Net present value assessment outcomes

Table 5.3 summaries the net market benefit in NPV terms for each credible option on a weighted basis across the three scenarios. The net market benefit is the gross market benefit (as set out in Table 5.1) minus the cost of each option (as outlined in Table 5.2), all in present value terms.

The table shows that corresponding ranking of each option, for each scenario with the options ranked in order of descending net benefits.

Table 5.3 – Present value of expected net benefits relative to the base case, $m 2017/18

Option	PV of Capital costs	PV of Operating costs	Weighted PV of gross benefits	Weighted NPV of benefits	Option ranking
Option 1	24.8	3.4	35.9	7.7	2
Option 2	**23.7**	**3.6**	**40.7**	**13.3**	**1**

5.4 Sensitivity analysis results

Ausgrid has undertaken a thorough sensitivity testing exercise to understand the robustness of the RIT-D assessment to underlying assumptions about key variables.

In particular, we have undertaken two tranches of sensitivity testing – namely:

- Step 1 – testing the sensitivity of the optimal timing of the project ('trigger year') to different assumptions in relation to key variables; and
- Step 2 – once a trigger year has been determined, testing the sensitivity of the total NPV benefit associated with the investment proceeding in that year, in the event that actual circumstances turn out to be different.

That is, Ausgrid has undertaken sensitivity analysis to first determine the optimal timing of the project, to conclude that a particular year represents the 'most likely' date at which the project will be needed.

Having assumed to have committed to the project by this date, Ausgrid has also looked at the consequences of 'getting it wrong' under Step 2 of the sensitivity testing. That is, if demand turns out to be lower than expected, for example, what would be the impact on the net market benefit associated with the project continuing to go ahead on that date.

We outline how each of these two steps have been applied to test the sensitivity of the key findings.

5.4.1 Step 1 – Sensitivity testing of the assumed optimal timing for each option

Ausgrid has estimated the optimal timing for each option based on the year in which the annualised cost of the project falls below the expected market benefit from commissioning the project that year. This process was undertaken for both the baseline set of assumptions and also a range of alternate assumptions for key variables.

This section outlines the sensitivity on the identification of the trigger year to changes in the underlying assumptions. In particular, the optimal timing of the options is found to be largely invariant to assumptions of:

- a 25 per cent increase/decrease in the assumed network capital costs;
- alternate forecasts of maximum demand growth, based on POE10 (high) and POE90 (low);
- a lower VCR ($90/kWh); and
- a lower discount rate of 4.19 per cent as well as a higher rate of 8.07 per cent.

The figures below outline the impact on the optimal trigger year for each option, under a range of alternate assumptions. They illustrate that the optimal commissioning date for all credible options is found to be 2024/25 under Option 2.

Figure 9 – Distribution of project need years under each sensitivity investigated – Option 1

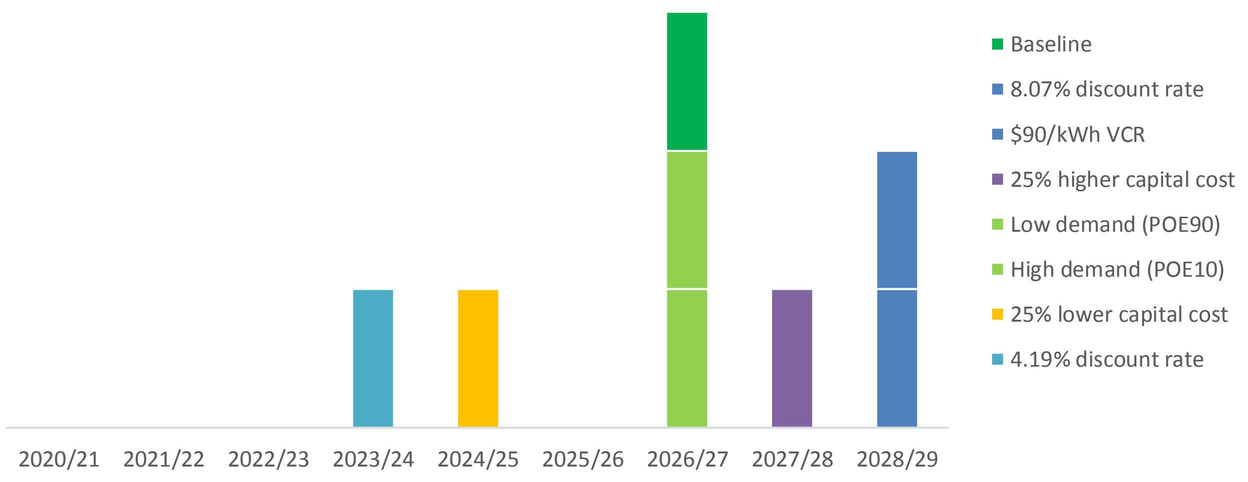
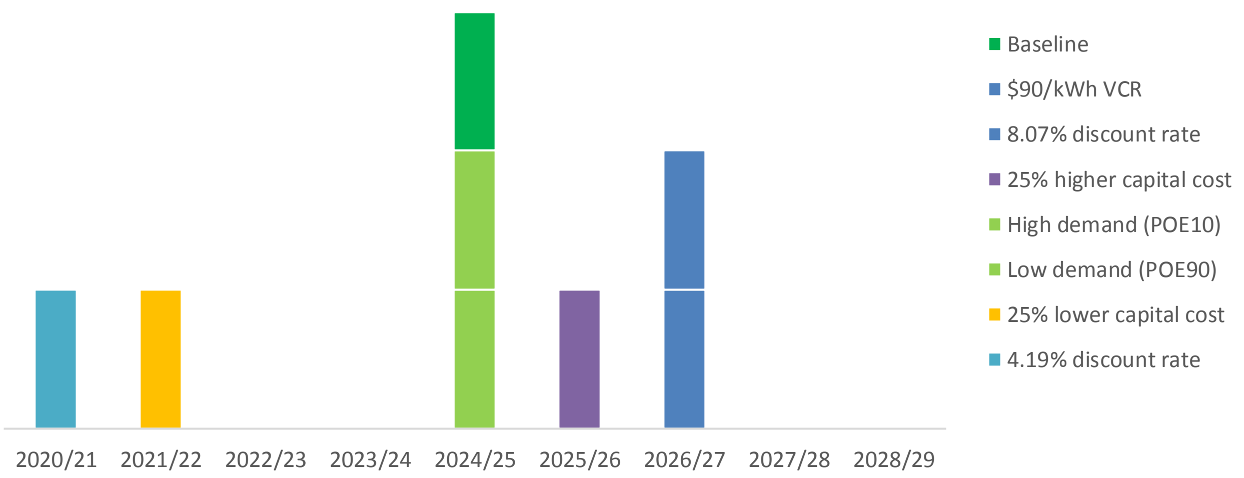


Figure 10 – Distribution of project need years under each sensitivity investigated – Option 2



On balance, Ausgrid considers that the identification of the central trigger years for all options has been robustly determined and tested.

5.4.2 Step 2 – Sensitivity testing of the overall net market benefit

Ausgrid has also conducted sensitivity analysis on the overall NPV of the net market benefit, based on the assumed option timing.

Specifically, Ausgrid has investigated the same sensitivities under this second step as the first step, ie:

- a 25 per cent increase/decrease in the assumed network capital costs;
- alternate forecasts of maximum demand growth, based on POE10 (high) and POE90 (low);
- a lower VCR ($90/kWh); and
- a lower discount rate of 4.19 per cent as well as a higher rate of 8.07 per cent.

All these sensitivities investigate the consequences of 'getting it wrong' having committed to a certain investment decision.

Table 4 presents the results of these sensitivity tests and for each sensitivity case labels the highest ranked option using bold text. The analysis reaffirms the finding that Option 2 is found to be the preferred credible option, and has a positive net market benefit for all sensitivities investigated.

Table 4 - Sensitivity testing results, $m 2017/18

Sensitivity	Option 1	Option 2
Baseline	7.3	**13.5**
25 per cent higher capital cost	1.1	**7.5**
25 per cent lower capital cost	13.6	**19.4**
Unserved energy under POE10	10.0	**16.3**
Unserved energy under POE 90	4.2	**10.1**
VCR $90/kWh	-2.6	**2.5**
4.19 per cent discount rate	18.9	**26.3**
8.07 per cent discount rate	-0.5	**4.4**

6 Proposed preferred option

Option 2 has been found to be the preferred option, which satisfies the RIT-D. It involves transferring the City East and Dalley Street substation loads to the Belmore Park zone substation in one 2×10 way duct lines and, subsequently, decommissioning the City East and Dalley Street substations. Ausgrid is the proponent for Option 2.

Option 2 offers the following benefits:

- it has significantly lower capital costs than Option 1 (i.e. it involves \$40.6 million of capital cost compared to \$51.9 million for Option 1);
- it involves excavating only one side of College Street to lay new cables (Option 1 requires both sides to be excavated);
- it provides greater network capacity than Option 1 (i.e. 90 MVA compared to 80 MVA); and
- it addresses condition issues at both the City East and Dalley Street zone substations.

In addition, both Option 1 and Option 2 have the significant benefit of being able to defer the likely build of a new zone substation in the CBD. In particular, if the City East and Dalley Street loads are not transferred to Belmore Park, then Ausgrid considers that a new zone substation would have to be constructed as soon as possible to cater for these loads. The estimated capital cost of such a substation is in the order of \$155 million and so the avoidance of such a cost represents a significant benefit to both credible options.[12]

The scope of Option 2 includes:

- installing one 2×10-way duct bank with $500mm^2$ copper cables on one side of College Street;
- measures to reduce the risk of duct bank common mode failure including altering the design of drop-in pits to limit the impact of a pit fire and having 500mm separation between banks;
- transfer of 11 kV load from the existing City East and Dalley Street zone substations to Belmore Park; and
- decommissioning of the existing City East and Dalley Street zone substations.

The estimated capital cost of Option 2 is \$40.6 million with a further \$3.4 million for decommissioning costs. Operating costs for Option 2 are assumed to be minimal given that it is expected new duct banks and feeders incur immaterial levels of maintenance over the 20 year period.

Ausgrid estimates that the environmental approval and construction timeline for Option 2 is 48 months, with commissioning of final stages expected during 2024/25. Final decommissioning of the existing zone substations and associated equipment at City East and Dalley Street is expected to be completed by 2025/26. Ausgrid intends to commence work on delivering Option 2 in 2018/19 (in particular, we intend to award the design and construction contract in July 2018, have environmental approvals finalised in August/September 2018 and to commence construction shortly after).

[12] While Option 1 and Option 2 will both defer the need for a new zone substation in the northern part of the CBD, Ausgrid has elected to not capture the determent benefit as the difference between capital costs that would occur in the base case, and those for Option 1 and Option 2. The reason for this is that this benefit overwhelms the other benefits (since it is around \$155m of capital cost being deferred) and is essentially the same for each option (since they both avoid this expenditure).

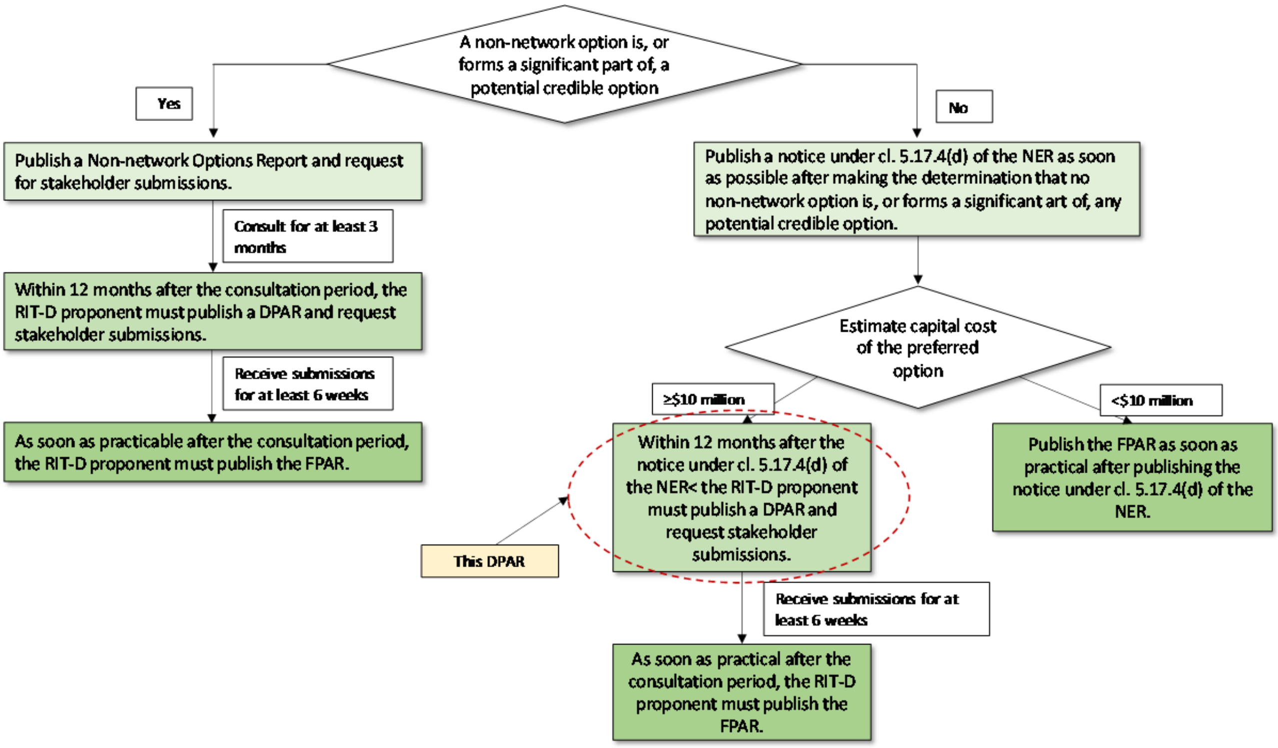
Appendix A – Checklist of compliance clauses

This section sets out a compliance checklist that demonstrates the compliance of this DPAR with the requirements of clause 5.17.4(j) of the National Electricity Rules version 103.

Rules clause	Summary of requirements	Relevant sections in the DPAR
5.17.4(j)	(1) a description of the identified need for the investment	2
	(2) the assumptions used in identifying the identified need	2.3, 4 & Appendix C
	(3) if applicable, a summary of, and commentary on, the submissions on the non-network options report	NA
	(4) a description of each credible option assessed	3
	(5) where a DNSP has quantified market benefits, a quantification of each applicable market benefit for each credible option;	5.1
	(6) a quantification of each applicable cost for each credible option, including a breakdown of operating and capital expenditure	3 & 5.2
	(7) a detailed description of the methodologies used in quantifying each class of cost and market benefit	2.3, 4 & Appendix C
	(8) where relevant, the reasons why the RIT-D proponent has determined that a class or classes of market benefits or costs do not apply to a credible option	Appendix D
	(9) The results of a net present value analysis of each of credible option and accompanying explanatory statements regarding the results	5
	(10) the identification of the proposed preferred option	6
	(11) for the proposed preferred option, the RIT-D proponent must provide: (i) details of technical characteristics; (ii) the estimated construction timetable and commissioning date (where relevant); (iii) the indicative capital and operating cost (where relevant); (iv) a statement and accompanying detailed analysis that the proposed preferred option satisfies the regulatory investment test for distribution; and (v) if the proposed preferred option is for reliability corrective action and that option has a proponent, the name of the proponent	6
	(12) Contact details for a suitably qualified staff member of the RIT-D proponent to whom queries on the draft report may be directed.	1.2

Appendix B – Process for implementing the RIT-D

For the purposes of applying the RIT-D, the NER establishes a three stage process: (1) the Non-Network Options Report (or notice circumventing this step); (2) the DPAR; and (3) the FPAR. This process is summarised in the figure below.



Appendix C – Additional detail on key assumptions

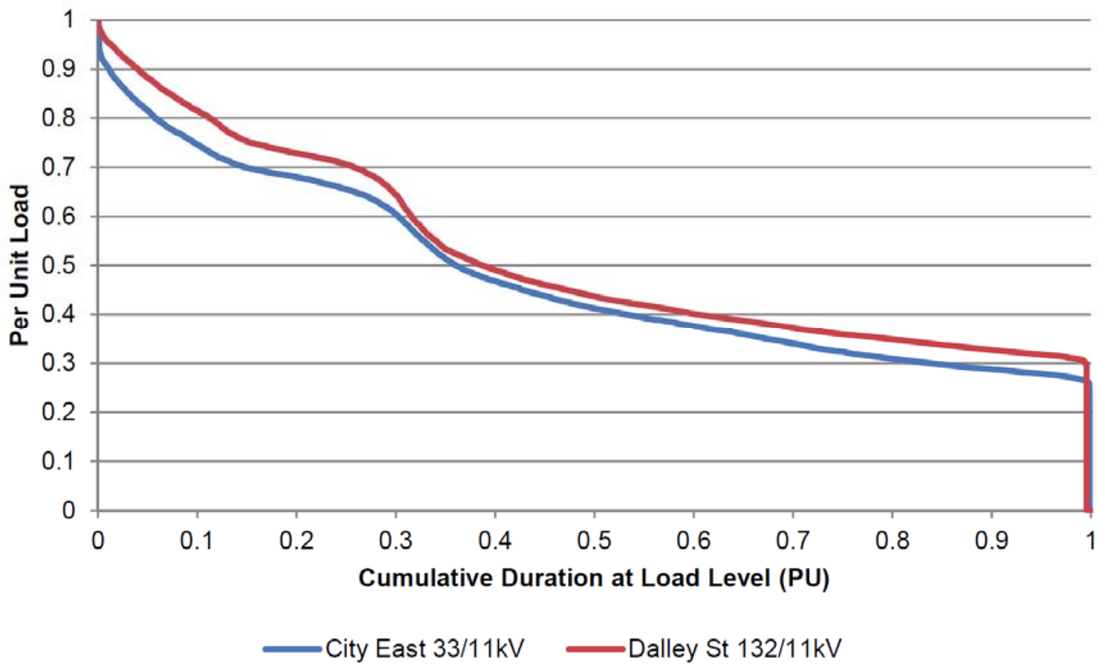
This appendix provides additional detail on key input assumptions that are used in the evaluation of the base case and the two credible options.

C.1 Charactertistic load duration curves

Load duration curves for City East and Dalley St zone substations are presented in Figure 11 below.

The load duration curves display similar characteristics because of the similar load types supplied by the substations. It is assumed that the load types supplied by these substations will not change substantially in to the future and therefore the load duration curves will maintain their characteristic shape regardless of the zone substation supplying the existing City East and Dalley Street load.

Figure 11: Load duration curves



C.2 Load transfer capacity and supply restoration

Dalley Street zone substation has potential 11kV interconnection with City East, City Central and City North Zones. In the event of a total loss of supply to Dalley Street, approximately 2.7 MVA of peak load can be recovered within days via the 11kV load transfer capacity of the existing network.

City East Zone has potential 11kV interconnection with Dalley Street Zone. In the event of a total loss of supply to City East, approximately 1.8 MVA of peak load can be recovered within days via the 11kV load transfer capacity of the existing network. A range of equipment outages are considered in this study.

In the event of an equipment outage, the network may be returned to a normal configuration by one of the following actions:

- repairing the failed equipment
- initiating a contingency plan
- replacing the failed equipment with spares.

The assumed supply restoration actions and the time taken to implement the action are detailed in the table below. These actions are the most likely actions for the contingencies considered in this planning study.

Table C.1: Equipment outage assumptions

Equipment outage	Action	Outage duration
Major compound insulated switchboard failure – Dalley Street zone substation	<u>Contingency plan</u> One of the following contingency plans is implemented: 1. Load is transferred from the failed switchboard to the spare switchgear located in the capacitor room. 2. The failed switchboard is removed and replaced with new switchgear because the spare switchgear has been previously utilized. 3. Load is transferred to an adjacent switchboard if the loading of the substation permits	Plan 1: 30 days Plan 2: 90 days Plan 3: 30 days
Major air insulated switchboard failure – Dalley Street zone substation	<u>Replace</u> The failed switchboard is replaced with parts that may be internally sourced, externally sourced or manufactured depending on the failure scenario.	21 days
Major compound insulated switchboard failure – City East zone substation	<u>Contingency plan</u> Ausgrid's emergency switch room is deployed and load is transferred from the failed switchboard <u>Contingency plan</u> One of the following contingency plans is implemented: 1. Ausgrid's emergency switch room is deployed and load is transferred from the failed switchboard 2. The failed switchboard is removed and replaced with new switchgear because the deployment of the emergency switch room is not feasible due to prior failures.	Plan 1: 30 days Plan 2: 90 days
Oil filled cable failure	<u>Repair</u> The cable is repaired on site.	35 days
Oil filled cable third party damage	<u>Repair</u> The cable is repaired on site. Additional time is typically required to repair third party damage.	35 days
Oil filled cable corrective action	<u>Repair</u> One of the following repairs may take place depending on the failure mode: 1. in service repair (65 per cent) 2. out of service repair (35 per cent)	1. In service repair (no outage) 2. 35 days
HSL cable failure	<u>Repair</u> The cable is repaired on site	10.5 days
HSL cable third party damage	<u>Repair</u> The cable is repaired on site. Additional time is typically required to repair third party damage	14 days
132kV gas-insulated switchgear end of life failure	<u>Replace</u> Gas insulated gear and adjacent switch are replaced by a 132kV ring main circuit breaker	90 days

C.3 Forecast availability of equipment

A range of models have been used to forecast the availability of equipment relevant to this RIT-D. These models utilise Ausgrid's historical outage records to determine the likelihood of failure. These models are combined with the estimates for repair or supply restoration time to determine the availability of equipment. The assumptions used to obtain the availability forecasts are provided in this section.

C.3.1 Availability of 11kV switchboards

For the purposes of this analysis, failures of 11kV switchboards are assumed to be non-repairable because typically the board is no longer functional following a failure (and hence is replaced or removed from service). Weibull analysis is used to derive a probability distribution function for the asset's age at time of failure. This function is denoted as f(t), where t is expressed in years. The parameters of the function are derived by considering the following information:

- the age of Ausgrid's in service 11kV switchboards;
- the age of functional failure for Ausgrid's failed switchboards; and
- the age of retirement for Ausgrid's switchboards that were retired before the point of functional failure.

The resultant Weibull parameters are given in the table below.

Table C.2: Switchboard parameters for the Weibull analysis

Equipment	Shape	Scale	Restore time
Compound insulated 11kV switchboard	4	63	90 days
Air insulated 11kV switchboard	4	75	90 days

The concept of conditional probability is used to evaluate the probability of failure (Pf) for each year in the planning period. The probability a switchboard failure occurring each year, given that the board has survived to the current age (T) is calculated by applying the Equation 1:

$$P_f = \frac{\int_t^{t+1} f(t)dt}{\int_T^{\infty} f(t)dt} \quad (1)$$

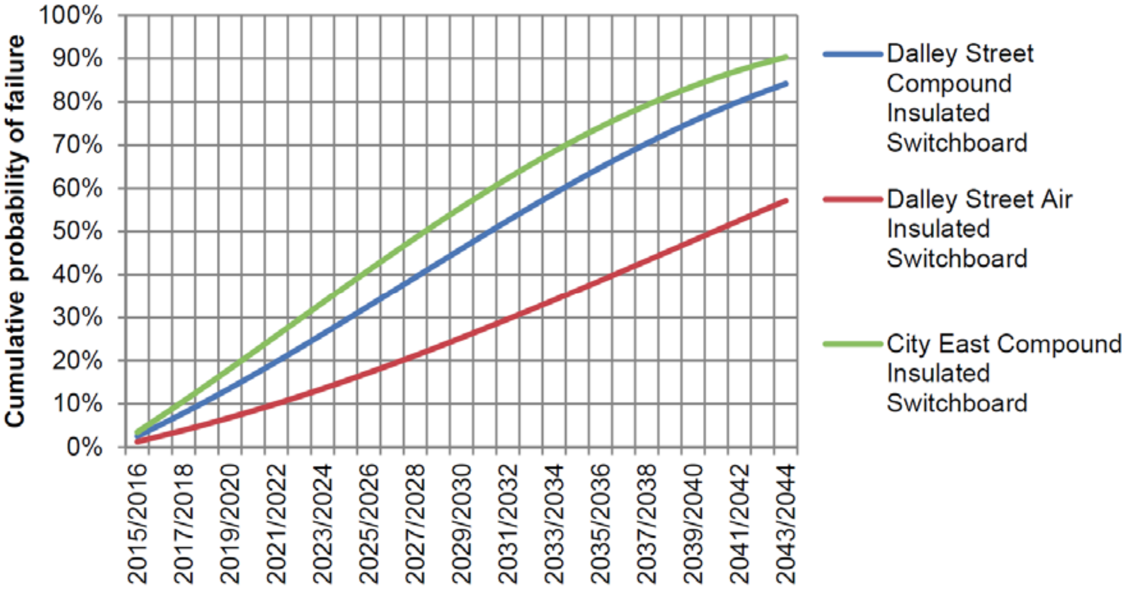
Unavailability is calculated by using a restore time, so the unavailability represents the percentage of time that a particular busbar is not available to supply load. The unavailability (U) of a switchboard is calculated for each year by applying Equation 2:

$$U = \frac{P_f \,.\, Outage\ Duration}{365} \quad (2)$$

This model is based on the assumption that the condition of a switchboard is dependent upon its age. In order to explore the possibility that each board is in better or worse condition than the population average, lower and upper bounds for U are calculated by either adding or subtracting ten years from the age of each board.

Figure 12 shows cumulative probability of failure for the Dalley Street and City East 11kV switchboards.

Figure 12: Cumulative probability of failure – 11kV switchboards



C.3.2 Availability of zone and subtransmission transformers

For the purposes of this analysis, zone and subtransmission transformer failures are categorised as end-of-life failures or repairable failures. Weibull analysis is used to derive a probability distribution function for the asset's age at time of end of-life failure. This function is denoted as f(t), where t is expressed in years. The parameters of the function are derived by considering the following information:

- The age of Ausgrid's in service transformers
- The age of functional failure for Ausgrid's failed transformers
- The age of retirement for Ausgrid's transformers that were retired before the point of functional failure.

The function is derived for each transformer type relevant to this study. The resultant Weibull parameters are given in Table C.3. Pf for transformers is also calculated by modifying Equation 3 as follows:

$$P_f = \frac{\int_t^{t+1} f(t)dt}{\int_t^{\infty} f(t)dt} \qquad (3)$$

This modification accounts for the assumption that failed transformers are replaced with spare transformers of an equivalent age.

The failure frequency (f) for repairable failures is also derived. The failure frequency derivation excludes any end-of-life failures.

Table C.3 Transformer parameters for the Weibull analysis

Transformer type	Shape	Scale	Replace time	f	Repair time
132/11kV transformer w/bushings	3.84	55.8	35 days	0.007	10 days
33/11kV transformer w/endboxes	3.77	113.9	35 days	0.003	10 days
132/33kV transformer w/bushings	2.22	177.9	35 days	0.022	10 days

The end-of-life unavailability (UEOL) and repairable unavailability (Urepair) are calculated by applying Equations 4 and 5. The total transformer unavailability is calculated taking the union of UEOL and Urepair as shown in Equation 6 below.

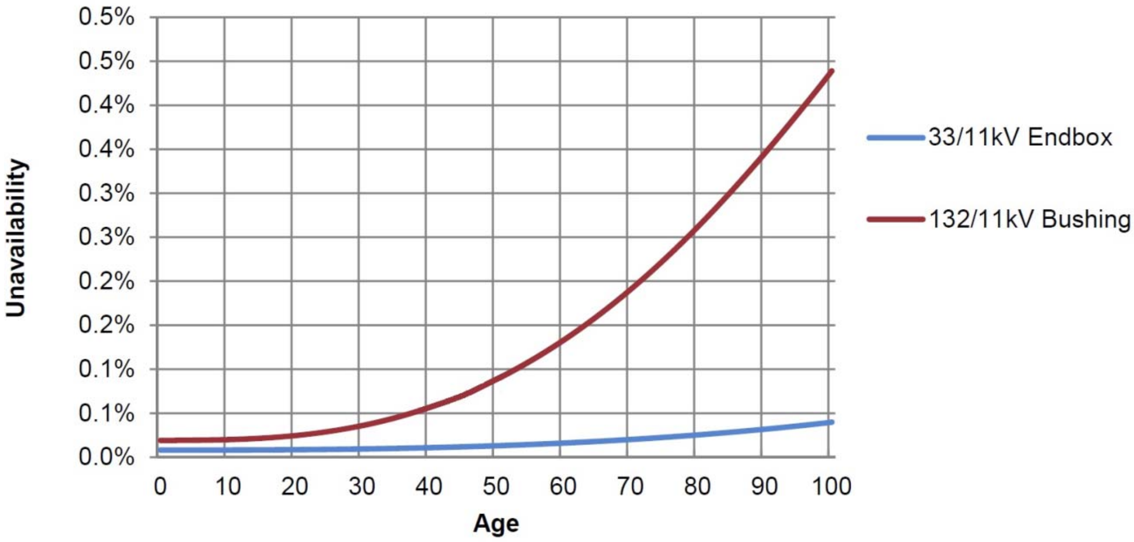
$$U_{EOL} = \frac{P_f\,.\,Replace\ Time}{365} \quad (4)$$

$$U_{repair} = \frac{f\,.\,Repair\ Time}{365} \quad (5)$$

$$U_{total} = U_{EOL} \cup U_{repair} \quad (6)$$

Figure 13 shows unavailability when the above equations are applied to transformers aged 0 – 100 years. This model is also based on the assumption that the condition of a transformer is dependent upon its age.

Figure 13: Unavailability of transformers



C.3.3 Avalaibility of other miscellaneous equipment

There are two sets of single phase 132kV gas-insulated switchgear installed at Dalley Street. This switchgear is unique in Ausgrid's network. There are also four sets of single phase 132kV circuit switches installed at Dalley Street. These switches are unique in Ausgrid's network.

There are six 33kV series reactors installed at City East. These reactors are unique in Ausgrid's network. All of these assets have been recommended for replacement due to poor condition.

For the purposes of this analysis, failures of 132kV gas-insulated switchgear, 132kV circuit switches and 33kV series reactors are assumed to be non-repairable because typically the board is no longer functional following a failure (and hence is replaced or removed from service). Due to the small size of these populations and lack of literature available internationally, it is necessary to assume Weibull parameters based on the most similar equipment and most likely actions to be taken.

Table C.4: Miscellaneous parameters for the Weibull analysis

Equipment	Shape	Scale	Restore time
132kV gas insulated switchgear	4	80	90 days
132kV circuit switch	4	80	90 days
33kV series reactor	4	80	90 days

Equation 1 is used to evaluate the probability of failure (Pf) for each year in the planning period. Equation 2 is used to evaluate the unavailability.

Table C.5 The table below shows the details of the 132kV switchgear included in this study.

Table C.5: 132kV switchgear details

Switchgear	Date commissioned	Number of assets
132kV gas insulated switchgear	14/10/1972	2
132kV circuit switch	14/10/1969	4
33kV series reactor	21/11/1964	6

C.3.4 Availability of distribution feeders

For underground 11kV distribution feeders supplied by Dalley Street and City East zone substations, the historical unavailability has been obtained from Ausgrid's SCADA system. These unavailabilities are detailed in the table below.

Table C.6: 132kV switchgear details

Substation	11kV feeder unavailability
City East	0.7 per cent
Dalley Street	1.1 per cent

These unavailabilities are applied to each individual feeder included in the analysis. An increase of 25% has been assumed for 11kV feeder unavailability to account for the extra length of 11kV feeders connecting City East and Dalley Street load to Belmore Park zone substation.

C.4 Direct costs of equipment failures

For the purposes of evaluating safety impacts, it is assumed that equipment outages have direct costs as per the table below. All costs are in 2013/14 real dollars.

For switchboard failures, these costs are based on the estimated cost of implementing the contingency plans described above. This cost includes 11kV feeder connections, protection and earthing designs, delivery costs and labour rates.

For cable outages, the costs are based on the historical average cost for each type of outage. These costs include labour rates, material costs and contracted services such as traffic control.

Transformer replacement costs are based on planning estimates for capital replacements. 33kV reactor, 132kV circuit switch and 132kV gas-insulated switchgear replacement costs are based on high level estimates.

Table C.7: Direct costs of equipment outages

Equipment outage	Direct cost
Major compound insulated switchboard failure – Dalley Street zone substation	$1,530,870 Contingency Plan 1: $1,530,870 Contingency Plan 2: Nil Contingency Plan 3: $306,174
Major air insulated switchboard failure – Dalley Street zone substation	$150,000
Oil filled cable corrective action	$11,207
Oil filled cable failure	$25,765
Oil filled cable third party damage	$216,477
33kV reactor end of life failure	$250,000
132/11kV transformer end of life failure (Dalley Street)	$6,000,000
33/11kV transformer end of life failure (City East)	$1,600,000
33kV series reactor end of life failure	$100,000
132kV circuit switch end of life failure	$4,000,000
132kV gas insulated switchgear end of life failure	$4,000,000

C.4 Estimating the value of avoided pollution risk at City East ZS

While not the key driver for the project, in the event of an incident involving fire and oil leak at City East zone substation, there is a risk of pollution of the surrounding area and/or waterways. Pollution of waterways in particular, would be an offence under the *Protection of Environment Operations Act 1997* for pollution of waters, which carries heavy penalties.

Ausgrid has estimated the value of eliminating this environmental risk using the following facts and assumptions:

- an oil spill of this nature is offence under the *Protection of Environment Operations Act 1997* for pollution of waters;[13]
    - an offence of this nature carries a potential $1 million penalty plus a further penalty of $120,000/day for each day the offence continues;
- the clean-up response for a spill of this nature is estimated to be in the order of $100,000 in $2017/18;
- the clean-up would require assistance from Sydney Ports and Emergency Services, and is likely to require several weeks to complete, based on advice provided by an Ausgrid's Environmental Services group.
    - our assumption is that it would be at least 15 days.
- a probability of occurrence is assumed to be 1 in a 50 year event (2 per cent) initially – this is expected to increase over time as City East zone substation is already 54 years old.

[13] See Section 123 of the *Protection of Environment Operations Act 1997*, available at: http://www9.austlii.edu.au/cgi-bin/viewdoc/au/legis/nsw/consol_act/poteoa1997455/s123.html

Appendix D – Market benefit classes considered not relevent

The market benefits that Ausgrid considers will not materially affect the outcome of this RIT-D assessment include:

- changes in voluntary load curtailment;
- costs to other parties;
- load transfer capability and embedded generators;
- option value;
- electrical energy losses; and
- deferring the need for unrelated network expenditure.

The reasons why Ausgrid considers that each of these categories of market benefit is not expected to be material for this RIT-D are outlined in the table below.

Table 8 – Market benefit categories under the RIT-D not expected to be material

Market benefits	Reason for excluding from this RIT-D
Changes in voluntary load curtailment	Ausgrid notes that the level of voluntary load curtailment currently present in the NEM is limited. Where the implementation of a credible option affects pool price outcomes, and in particular results in pool prices reaching higher levels on some occasions than in the base case, this may have an impact on the extent of voluntary load curtailment. Ausgrid notes that none of the options are expected to affect the pool price and so there is not expected to be any changes in voluntary load curtailment.
Costs to other parties	This category of market benefit typically relates to impacts on generation investment from the options. Ausgrid notes that none of the options will affect the wholesale market and so we have not estimated this category of market benefit.
Changes in load transfer capacity and embedded generators	Load transfer capacity between substations is predominantly limited by the high voltage feeders that connect substations. Credible options under consideration do not affect high voltage feeders and therefore are unlikely to materially change load transfer capacity. Further, credible options are unlikely to enable embedded generators in Ausgrid's network to be able to take up load given the size and profile of the load serviced by network assets currently considered in the credible options. Consequently, Ausgrid has not attempted to estimate any benefits from changes in load transfer capacity and embedded generators.
Option value	While both Option 1 and Option 2 will defer the need for a new zone substation in the northern part of the CBD, the resulting deferral benefit overwhelms the other benefits (approximately $155m of capital cost being deferred) and is the same for each option, as they both avoid this expenditure. Ultimately, the deferral benefit does not assist in identifying a preferred option.
Changes in electrical energy losses	Ausgrid does not expect that any of the credible options considered would lead to significant changes in network losses and so have not estimated this category of market benefits.
Deferring the need for unrelated network expenditure	While Option 1 and Option 2 will both defer the need for a new zone substation in the northern part of the CBD, Ausgrid has elected to not capture the determent benefit as the difference between capital costs in the base case, and those for Option 1 and Option 2. The reason for this is that this benefit overwhelms the other benefits (since it is around $155m of capital cost being deferred) and is essentially the same for each option (since they both avoid this expenditure).