Ensuring reliability requirements in the Lower North Shore area

DRAFT PROJECT ASSESSMENT REPORT

25 MAY 2018

Ausgrid

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Addressing reliability requirements in the Lower North Shore area

Draft Project Assessment Report – May 2018

Contents

Executive Summary

This report investigates the most economic option for mitigating the risks associated with fluid-filled feeders installed on the Lower North Shore in the 1970s

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 to the Lower North Shore network area going forward.

In particular, the underground electricity distribution lines ('feeders') supplying the Castle Cove and Mosman zone substations were commissioned in the 1970s, and are now reaching, or past, the end of their technical lives. These feeders utilise self-contained fluid filled cables, which are now considered an obsolete and dated technology. They are becoming less reliable and expose Ausgrid's customers in the Lower North Shore network area to a level of reliability that exceeds the allowance applicable to Ausgrid under current standards if nothing is done.

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

Ausgrid identified the need to replace the feeders supplying the Mosman substation in 2017 and identified a preferred solution to mitigating the identified risks.

Ausgrid undertook a range of community engagement activities seeking feedback on the preferred replacement option identified in 2017. These activities included meeting with Willoughby City Council, North Sydney Council and Mosman Council, as well as having representatives from the Ausgrid project team speak to many businesses and visiting residents in these council areas. This consultation included visiting and distributing project information to residents along the impacted streets. Feedback received was very helpful and resulted in a number of refinements to the preferred solution. Ausgrid wishes to thank all those consulted with for their time and suggestions.

Rule changes to the National Electricity Rules (NER) in July 2017 have meant that the replacement plans for ageing feeders are now subject to the RIT-D. Accordingly, Ausgrid has initiated this RIT-D for replacing ageing feeders supplying the Mosman zone substation in order to investigate and consult on options to ensure Ausgrid is able to satisfy the reliability and performance standards that it is obliged to meet.

Two credible network options have been assessed

Ausgrid has identified two network options that either replace the existing Castle Cove feeders by installing two new 132kV feeders from the Willoughby Subtransmission Substation (STS) to Mosman via Cremorne Junction or undertaking a like-for-like replacement of the existing Castle Cove feeders.

The two credible options are summarised below. All costs in this section are in real \$2017/18, unless otherwise stated.

Table E.1 – Summary of the credible options considered

Overview	Key components	Length of new feeders	Estimated capital cost
Option 1 – new feeders from Willoughby STS to Mosman via Cremorne Junction	• Installation of two new 132kV feeders connecting Willoughby to Mosman using modern XLPE cable to replace existing Castle Cove to Mosman feeders.	6.6km	$28.9 million
Option 2 – like-for-like replacement of existing Castle Cove to Mosman feeders	• Replacement of existing Castle Cove to Mosman feeders like-for-like using two new XLPE cable feeders.	8.6km	$38.1 million

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 Mosman zone substation 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 the identified need

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 Net Present Value (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 the table below.

Table E.2 – Summary of the three scenarios investigated

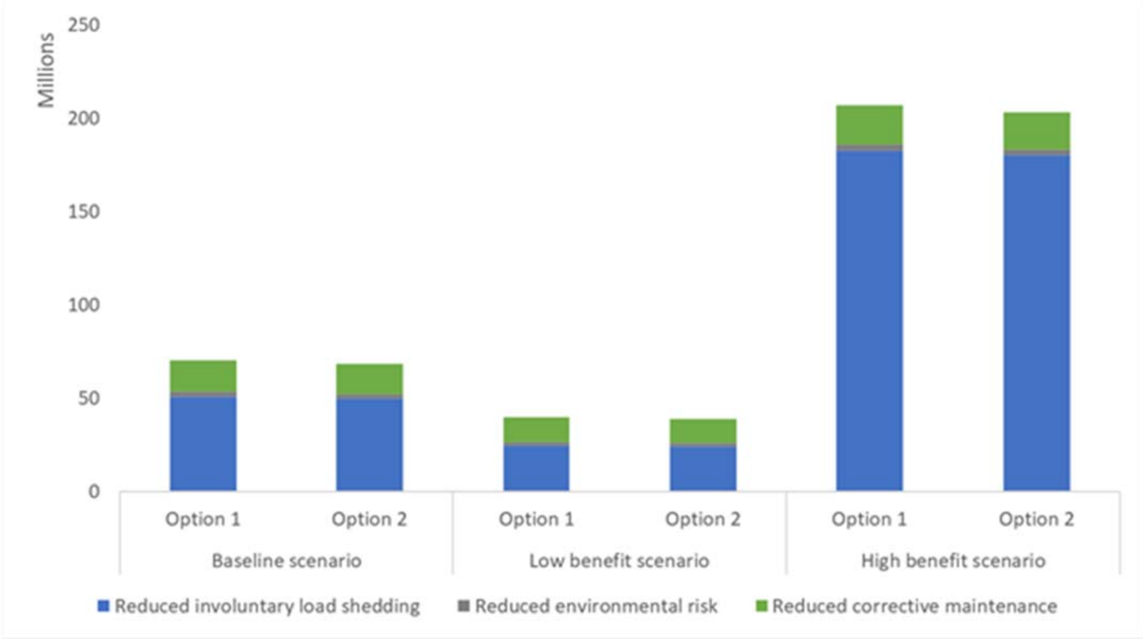
Variable	Scenario 1 – baseline	Scenario 2 – low benefits	Scenario 3 – high benefits
Demand	POE50	POE90	POE10
VCR	$40/kWh (Derived from the AEMO VCR estimates)	$28/kWh (30 per cent lower than the central, AEMO-derived estimate)	$90/kWh (Consistent with the recent IPART review of transmission reliability standards for this area)
Commercial discount rate	6.13 per cent	8.07 per cent	4.19 per cent

Option 1 has the highest expected net market benefits, under all scenarios

Both options are found to have essentially the same overall benefit. This is driven by the fact that both options are assumed to be commisioned a year apart and so avoid similar levels of expected unserved energy and corrective maintenance costs. Option 1 has marginally higher benefits than Option 2 on account of it being commisioned a year earlier.

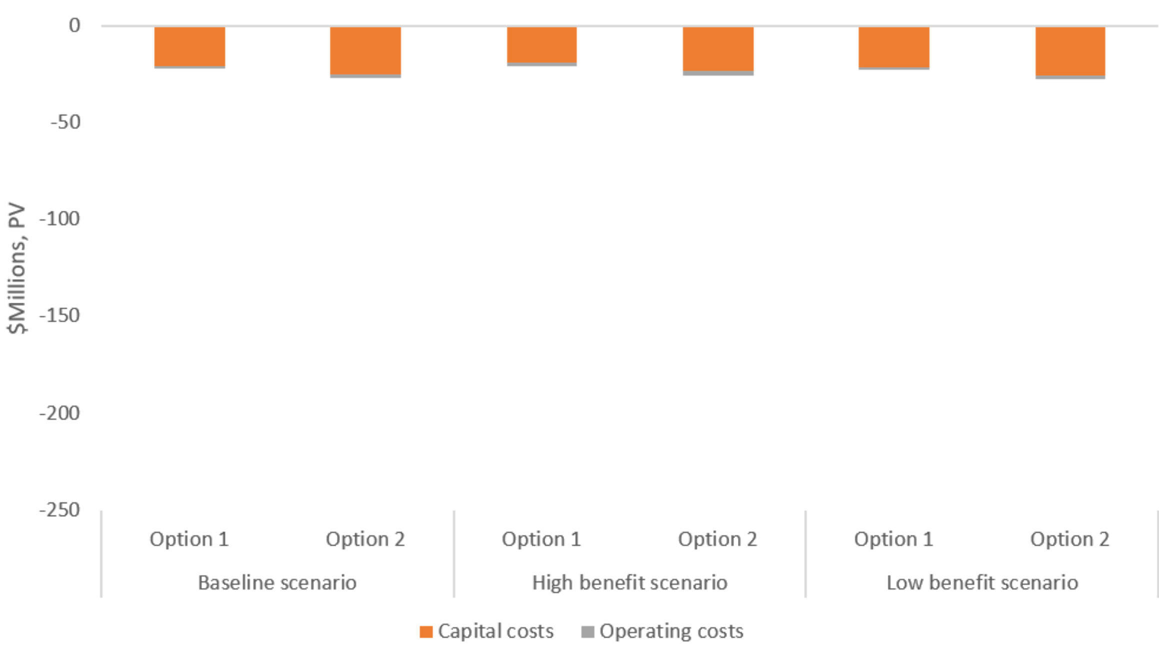
The primary benefit is estimated to be avoided unserved energy for both options on account of the increasing likelihood of failure of the assets in question, which are nearing the end of their technical lives.

Figure E.1 – Breakdown of gross economic benefits of each credible option relative to the base case



The figure below provides a breakdown of costs relating to each credible option. Under all scenarios, Option 1 involves the lowest capital cost due to it requiring approximately two fewer feeder kilometres. Not only does this result in fewer materials in terms of actual cables, but also the materials associated with facilitating the use of the feeders. For instance, by reducing the length of the feeder, there is a commensurate decrease in the need for other infrastructure such as joints and bays.

Figure E.2 – Breakdown of gross costs of each credible option relative to the base case



The table 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 1 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 1 to generate two more additional years of avoided cost benefits compared to Option 1. Option 1 also involves approximately $9 million less in capital costs than Option 2 on account of the shorter feeders required.

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

Option	Capital costs	Operating costs	Avoided costs	USE benefits	Weighted NPV	Ranking
Option 1	-20.7	-1.4	19.6	77.3	74.8	1
Option 2	-25.1	-1.8	18.8	76.1	68.0	2

Option 1 is the preferred option at this draft stage

Option 1 has been found to be the preferred option, which satisfies the RIT-D. It involves the replacement of the two existing feeders from Castle Cove to Mosman using two new installations at the Willoughby STS. Specifically, this option involves the installation of two new 132kV feeders from Willoughby STS to Mosman zone substation. These new feeders will be routed to Mosman via the proposed Cremorne Junction zone substation site.

The scope of the project includes:

- works at Willoughby STS and Mosman zone substation to facilitate new 132kV feeder connections;
- installation of a dual circuit 132kV feeder approximately 7km in length between Willoughby STS and Mosman zone substation; and
- control and protection communication upgrades at the Willoughby STS and Mosman zone substation to accommodate the new feeders.

The estimated capital cost of this option is approximately $28.9 million. Ausgrid assumes that the necessary construction to install the new feeders would commence in 2018/19 and end in 2021/22. One the new installation is complete, operating costs are expected to be $150,000 per annum (around 0.5 per cent of capital expenditure).

Ausgrid considers that this DPAR, and the accompanying detailed analysis, identify Option 1 as the preferred option and that this satisfies the RIT-D. Ausgrid is the proponent for Option 1.

How to make a submission and next steps

Ausgrid welcomes written submissions on this DPAR. Submissions are due on or before 6 July 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

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 to the Lower North Shore network area going forward.

In particular, the underground electricity distribution lines ('feeders') supplying the Castle Cove and Mosman zone substations were commissioned in the 1970s, and are now reaching, or past, the end of their technical lives. These feeders utilise self-contained fluid filled (SCFF) cables, which are now considered an obsolete and dated technology. The implication is that these assets are less reliable and expose Ausgrid's customers in the Lower North Shore network area to a level of reliability that exceeds the allowance applicable to Ausgrid under current standards.

Ausgrid identified the need to replace the feeders supplying the Mosman substation in 2017 and identified a preferred solution to mitigating the identified risks.

Ausgrid undertook a range of community engagement activities seeking feedback on the preferred replacement option identified in 2017. These activities included meeting with Willoughby City Council, North Sydney Council and Mosman Council, as well as having representatives from the Ausgrid project team speak to many businesses and visiting residents in these council areas. This consultation included visiting and distributing project information to residents along the impacted streets. Feedback received was very helpful and resulted in a number of refinements to the preferred solution. Ausgrid wishes to thank all those consulted with for their time and suggestions.

Rule changes to the National Electricity Rules (NER) in July 2017 have meant that the replacement plans for ageing feeders are now subject to the RIT-D. Accordingly, Ausgrid has initiated this RIT-D for replacing ageing feeders supplying the Mosman zone substation in order to investigate and consult on options to ensure Ausgrid is able to satisfy the reliability and performance standards that it is obliged to meet.

Ausgrid has determined that non-network solutions are unlikely to form a standalone credible option, or form a significant part of a credible option, as set out in the separate notice released in accordance with clause 5.17.4(d) of the NER.

1.1 Role of this draft report

Ausgrid has prepared this DPAR in accordance with the requirements of the 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.

The purpose of the DPAR is to:

- describe the identified need Ausgrid is seeking to address, together with the assumptions used in identifying it;
- provide a description of each credible option assessed;
- quantify relevant costs and market benefits for each credible option;
- describe the methodologies used in quantifying each class of cost and market benefit;
- provide reasons why Ausgrid has determined that classes of market benefits or costs do not apply to a credible option(s);
- present the results of a net present value analysis of each credible option and accompanying explanation of the results; and
- identify the proposed preferred option.

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.

The entire RIT-D process is detailed in Appendix B. The next steps for this particular RIT-D assessment are discussed further below.

1.2 Submissions and queries

Ausgrid welcomes written submissions on this DPAR. Submissions are due on or before 6 July 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

Submissions will be published on the Ausgrid website. If you do not want your submission to be publicly available please clearly stipulate this at the time of lodgement.

2 Description of the identified 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.

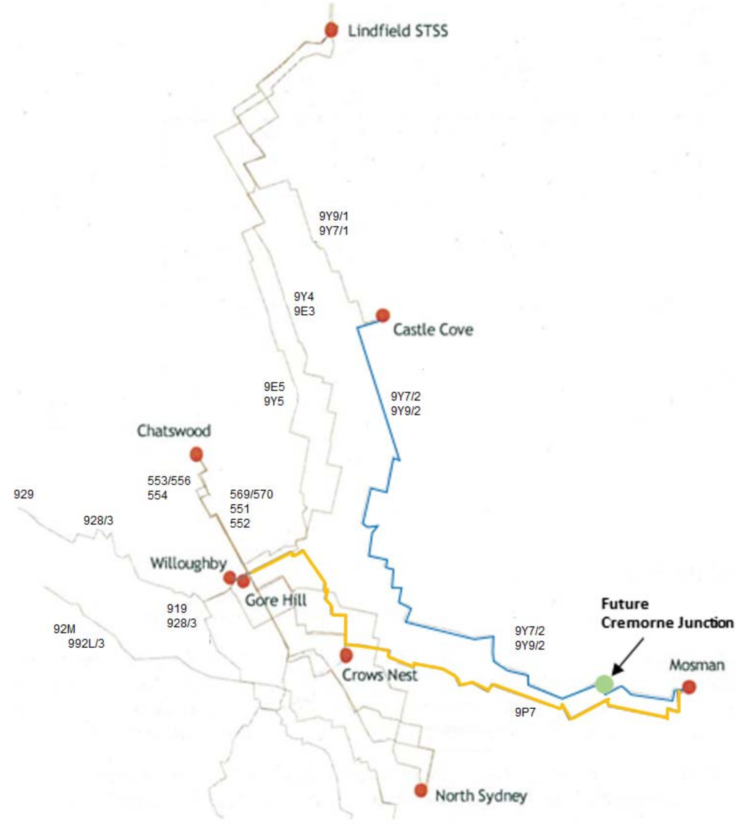
2.1 Overview of the Lower North Shore area

The Lower North Shore load area extends from Chatswood and Castle Cove in the north to North Sydney in the south, and east to Mosman. The distribution network:

- is supplied from TransGrid's transmission system at Sydney East via four 132kV feeders to Lindfield Subtransmission Switching Station (STSS);
- includes Castle Cove, Mosman, Crows Nest, North Sydney and Royal North Shore Hospital 132/11kV zone substations and Willoughby Subtransmission Substation (STS), which are supplied at 132kV from Lindfield STSS;
- includes 33/11kV zone substations at Chatswood and Gore Hill, which are supplied radially at 33kV from Willoughby STS;
- supplies high rise commercial load in Chatswood and North Sydney areas;
- predominantly serves residential and commercial load; and
- includes the 33kV supplies to major customers, the Lane Cove Tunnel, Railcorp (St Leonards) and Gore Hill Technology Park.

The figure below illustrates the geographic network area[1] of the area as well as the eight zone substations that service the region (i.e. the two 132kV zone substations, five 132/11kV zone substations and two 33/11kV zone substations) shown by red circles. The figure also highlights the connections between the Castle Cove and Mosman zone substations (in blue) and the connections between the Willoughby STS and Mosman zone substation (in orange).

Figure 2.1 – Lower North Shore network area



[1] The figure provides an indication of the geographic region of the Lower North Shore area. It is not intended to be an accurate depiction of the distribution network.

The figure above also shows the location of a site Ausgrid has procured for a future Cremorne Junction zone substation. This substation is not expected to be required in the next 20 years but depends critically on load growth in the area and the condition of switchgear at the existing Mosman zone substation going forward.

The region has a mixture of development ranging from low density, but high value residential premises, to high-rise commercial development. There are areas of significant commercial development which follow the rail corridor from Chatswood to North Sydney.

The network area is heavily congested and, as a result, all sub-transmission feeders and most 11kV feeders within the area have been constructed underground. Any new feeders installed in the area will also need to be constructed underground.

The Mosman zone substation, located in the east of the network, is currently supplied by three 132kV underground feeders – namely:

- two from the Castle Cove zone substation (see the blue line in Figure 2.1); and
- one from the Willoughby STS (see the grey line in Figure 2.1).

The two feeders that connect Castle Cove to Mosman are 8.6km in length and were commissioned in 1971, while the feeder connection Willoughby and Mosman is 6.9km in length and was commissioned in 1975.

Owing to their age, the underground feeders connecting Castle Cove and Willoughby are now an obsolete technology (as are the existing feeders connecting Willoughby and Mosman). As a result, they require specialist skills to repair and maintain, outage times can be lengthy, and spares are not readily available. Further, the age of the assets has led to performance issues, including:[2]

- A low but increasing probability of a substantial proportion of Castle Cove and Willoughby experiencing an extended blackout:
    - Ausgrid's risk and outage modelling for example, estimates that the aggregated expected unserved energy associated with these feeders is estimated to be approximately 240MWh in the FY2020-2024 regulatory period if nothing is done to address this risk.
- The feeders have experienced fluid leaks over the past 15 years:
    - a fluid leak in 2014 of one of the Castle Cove feeders resulted in a warning from the Environmental Protection Authority (which has been addressed);
    - damage to the Willoughby feeder in 2016 caused a fluid leak; and
    - combined, these feeders accounted for 2.75 per cent of the environmental risk assigned to all of Ausgrid's fluid filled cables network in 2017.
- Insulation resistance testing indicates that there may be problems with the outer serving of the cables, with the risk of more fluid leakages going forward.

A risk based cost-benefit analysis and environmental assessment has determined that the benefits of reduced expected unserved energy and avoided environmental impact exceed the annualized cost of replacing the asset from 2018/19 onwards.

Accordingly, Ausgrid has initiated this RIT-D in order to identify a preferred option that would ensure Ausgrid is able to satisfy its reliability and performance standards in supplying the Lower North Shore load area in light of these emerging risks.

[2] These performance issues pertain to the feeders connecting Castle Cove and Willoughby, not the feeders connecting Willoughby and Mosman.

2.2 Overview of Ausgrid's relevant distribution reliability standards

All New South Wales electricity distribution businesses, including Ausgrid, are obliged to comply with reliability and performance standards as part of their distributor's license.[3] These standards are determined by the New South Wales Government.

At a high-level, the reliability and performance standards are specified in terms of both:

- the average frequency of interruptions a customer may face each year; and
- the average time those outages may last.

Specifically, under the current Ausgrid license, reliability and performance standards are expressed in two measures – namely:

- the System Average Interruption Frequency Index – 'SAIFI' – which measures the number of times on average that customers have their electricity interrupted over the year;[4] and
- the System Average Interruption Duration Index – 'SAIDI' – which measures the total length of time (in minutes) that, on average, a customer would have their electricity supply interrupted over a given period.[5]

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 these measures are. Reliability standards applied to distribution networks typically set minimum requirements in relation to each of these two measures.

The current reliability standards applying to the Lower North Shore network area (classified as an 'urban' feeder type) are shown in Table 2.1 below.

Table 2.1 – Current distribution reliability standards applying to Ausgrid[6]

Feeder type	Network Overall Reliability Standards		Individual Feeder Reliability Standard	
	SAIDI (Minutes per customer)	SAIFI (Number per customer)	SAIDI (Minutes per customer)	SAIFI (Number per customer)
Urban	80	1.2	350	4

2.3 Key assumptions underpinning the identified need

The need to undertake action is predicated on the deteriorating condition of the two existing 132kV underground feeders from the Castle Cove zone substation to the Mosman zone substation 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 assumption 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.

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[3] Granted by the Minster for Industry, Resources and Energy under the *Electricity Supply Act 1995 (NSW)*.
[4] SAIFI is calculated as the total number of interruptions that have occurred during the relevant period, divided by the number of customers. Momentary interruptions (which in NSW are currently defined as interruptions less than one minute) are typically not included.
[5] SAIDI is calculated as the sum of the duration of all customer interruptions over the period divided by the number of customers. Momentary interruptions (i.e. those of less than one minute) are typically not included.
[6] The Hon. Anthony Roberts MP Minister for Industry, Resources & Energy, Reliability and Performance Licence Conditions for Electricity Distributors, 1 December 2016, pp. 18-19 - available at: https://www.ipart.nsw.gov.au/files/sharedassets/website/shared-files/licensing-administrative-electricity-network-operations-proposed-new-licence-conditions/ausgrid-ministerial-licence-conditions-1-december-2016.pdf

2.3.1 Ageing feeders supplying the Castle Cove and Mosman zone substations are expected to increase the risk of involuntary load shedding going forward

The 132kV cable feeders 9Y7 and 9Y9 supply Castle Cove and Mosman Zone Substations from Lindfield STS. The cable section between Castle Cove and Mosman (9Y7/2 and 9Y9/2) is fluid-filled.

The simultaneous outage of feeders 9Y7/2 and 9Y9/2 would take both Castle Cove and Mosman zone substations out of service as there are no 132kV feeder circuit breakers at each substation. A third, normally on stand-by, fluid filled feeder (9P7) from Willoughby to Mosman Zone Substation could be energised to supply Mosman substation by disconnecting bonds on feeders 9Y7/2 and 9Y9/2, and would have to be reversed to restore normal supply.

The concurrent outage of these feeders would result in the loss of supply to Castle Cove and Mosman zone substations. Partial loads would be recovered via 11kV load transfer to nearby zone substations using existing connections after a time delay (switching time). Essentially there is a low, but increasing, probability that a significant portion of the customers in this area will experience a very long blackout. Based Ausgrid's cable failure model, the aggregated expected unserved energy associated with these feeders has been calculated to be approximately 240MWh in the next five years.

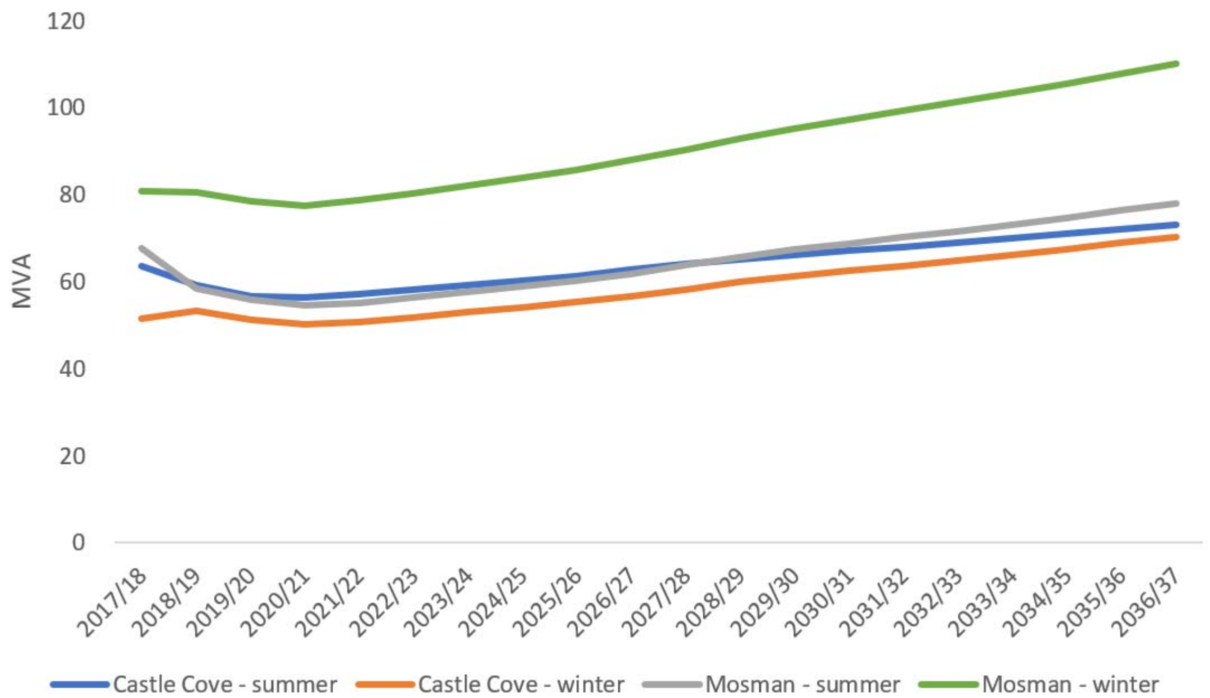
Cables 9Y7/2 and 9Y9/2 have experienced moderate fluid leaks over the past 15 years. Based on leakage data, along with an assessment of the environmental sensitivity along the cable route, the 2017 review of fluid filled 132kV cable environmental risk assessed cables 9Y7/2 and 9Y9/2 as contributing 1.63 per cent and 1.12 per cent of the total environmental risk assigned to Ausgrid's fluid filled cable population.

Insulation resistance testing indicates that there may be problems with the outer serving of the cables, which could lead to fluid leaks in the future. Our cable failure model forecasts that the reliability of these cables will deteriorate into the future if they are not replaced.

The cables supply Castle Cove and Mosman Zone Substations in the Lower North Shore area and their integrity are essential to ensure reliable supply for customers in these areas.

Both these substations are considered to serve an enduring need for distributing electricity in the Lower North Shore network area. Each of these two substations are expected to serve between 50 to 110 MVA of load between 2017/18 and 2036/37, as shown below.

Figure 2.2 – Castle Cove and Mosman substation load forecasts



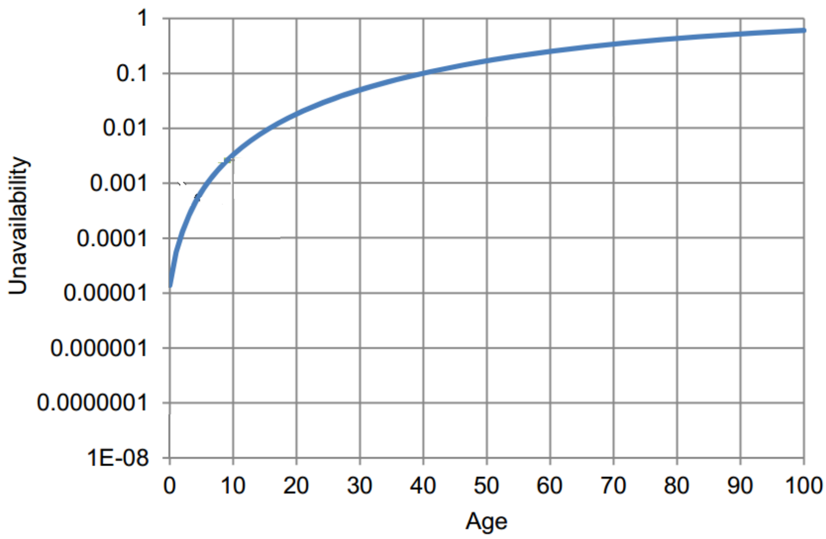
The potential for further cable fluid leaks, poor test results and increased rates of corrective work for these cables support the case to replace the remaining sections of aged fluid filled cables.

2.3.2 Probability of assets failing increases with age

Network asset failure probabilities and asset unavailability have a significant effect on the expected level of involuntary load shedding. Ausgrid has adopted well-accepted models for feeders to estimate the probability of failure. In general, the probability of failure increases with asset age.

The figure below shows unavailability plotted, on a logarithmic scale, for a representative 10km stretch of fluid-filled cables aged zero to one hundred years.

Figure 2.3 – Unavailability of fluid-filled feeders



This model is also based on the assumption that the condition of a cable is dependent upon its age. The Crow-AMSAA model shows that the availability of fluid-filled cables is expected to decline significantly if the cables are retained past an age of 50 years. Ausgrid considers this methodology is consistent with industry practice. A detailed discussion of the probability of failure and asset availability is provided in Appendix D.

2.3.3 Feeder redundancy exists but capacity to undertake load transfers are limited

The level of cost expected from any involuntary load shedding is dependent on underlying assumptions relating to the level of redundancy in feeders and the capacity to transfer load to other substations that could supply load currently served by the Castle Cove and Mosman substations.

Current supply arrangements for these zone substations have a degree of redundancy. As noted above, multiple feeders supply each substation and therefore load could be transferred to the two remaining feeders should one of the fluid-filled feeders experience a fault or be out of service. However, outages of multiple feeders supplying each substation would likely lead to some degree of involuntary load shedding. Further, as feeders age, the likelihood of multiple feeder failures increases that in turn is likely to lead to involuntary load shedding.

In addition, while feeder 9P7 is currently on stand-by, it has a limited rating due to the concurrent presence of other 132kV feeders in the same trench.

In the event of multiple failures, there is limited capacity to move load away from the Castle Cove and Mosman substations given network constraints in the Lower North Shore network area. Ausgrid estimates that the capacity to transfer is limited to 18 MVA, which is small relative to the overall demand of around 80 MVA. Consequently, restoration of supply to customers these areas would depend on the time needed to return feeders to service.

Both the degree of redundancy and the ability to transfer load elsewhere have been taken into account by Ausgrid in forecasting expected unserved energy.

3 Two credible options have been assessed

This section provides descriptions of the two credible options Ausgrid has identified as part of its network planning activities to date.

In particular, Ausgrid has identified two network options that either replace the existing Castle Cove feeders by installing two new 132kV feeders from the Willoughby STS to Mosman via Cremorne Junction or undertaking a like-for-like replacement of the existing Castle Cove feeders.

The two credible options are summarised below. All costs in this section are in real $2017/18, unless otherwise stated.

Table 3.1 – Summary of the credible options considered

Overview	Key components	Length of new feeders	Estimated capital cost
Option 1 – new feeders from Willoughby STS to Mosman via Cremorne Junction	• Installation of two new 132kV feeders connecting Willoughby to Mosman using modern XLPE cable to replace existing Castle Cove to Mosman feeders.	6.6km	$28.9 million
Option 2 – like-for-like replacement of existing Castle Cove to Mosman feeders	• Replacement of existing Castle Cove to Mosman feeders like-for-like using two new XLPE cable feeders.	8.6km	$38.1 million

One further option was considered in addition to those set out in Table 3.1, which involves the use of demand management to defer the timing of the network solution. However, this option was found to be non-credible. This option is discussion in section 3.3 below.

3.1 Option 1 – New feeders from Willoughby to Mosman (via Cremorne Junction)

This option involves the replacement of the two existing feeders from Castle Cove to Mosman using two new installations at the Willoughby STS. Specifically, this option involves the installation of two new 132kV feeders from Willoughby STS to Mosman zone substation. These new feeders will be routed to Mosman via the proposed Cremorne Junction zone substation site.

The scope of the project includes:

- works at Willoughby STS and Mosman zone substation to facilitate new 132kV feeder connections;
- installation of a dual circuit 132kV feeder approximately 6.6km in length between Willoughby STS and Mosman zone substation; and
- control and protection communication upgrades at the Willoughby STS and Mosman zone substation to accommodate the new feeders.

Ausgrid has identified the following benefits that are related to proceeding with Option 1 as set out above:

- improved reliability and mitigate identified risks;
- shorter route than a like-for-like replacement;
- enables connection to future Cremorne Junction zone substation at some point in the future; and
- potential fund contribution from Roads and Maritime Services (RMS), if a change in the feeders route is required due to the approval and subsequent construction of the Western Harbour Tunnel and Northern Beaches Link.

The estimated capital cost of this option is approximately $28.9 million. Ausgrid assumes that the necessary construction to install the new feeders would commence in 2018/19 and end in 2021/22, with commissioning occurring in the same year.

It is anticipated that a tradition turn-key design and construct model using external contractors will be used. This will incorporate trenching and feeder installation to achieve the nominated feeder ratings. However, commissioning and other electrical works will be carried out by Ausgrid staff.

One the new installation is complete, operating costs are expected to be $150,000 per annum (around 0.5 per cent of capital expenditure).

3.2 Option 2 – Like-for-like replacement of existing Castle Cove to Mosman feeders

This option involves a like-for-like replacement of the existing feeders that connect Castle Cove zone substation to Mosman zone substation.

The scope of the project includes:

- replacing the existing feeders connecting Castle Cove and Mosman like-for-like using modern XLPE cables totalling 8.6km in length.

While proceeding with option 2 has the benefit of mitigating identified network and environmental risks, Ausgrid has identified various risks and drawbacks associated with this option, compared to Option 1 – namely:

- a longer feeder route than Option 1 (by approximately 2km);
- it requires the installation of new feeders to connect to the future Cremorne Junction zone substation; and
- the simultaneous loss of feeders connecting Willoughby to Castle Cove or Castle Cove to Mosman will cause an outage of both Castle Cove and Mosman (whereas under Option 1 only one of the zones would be lost).

The estimated cost of this option is approximately $38.1 million. Ausgrid assumes that the like-for-like replacement would commence in 2018/19, with the replacement scheduled to finish in 2022/23, with commissioning occurring in the same year. Once the replacement is complete, operating costs are expected to be approximately $200,000 per annum (around 0.5 per cent of capital expenditure).

3.3 Options considered but not progressed

Ausgrid has also considered the ability of any non-network solutions to assist in meeting the identified need. Specifically, an analysis of non-network options considered how demand management could defer the timing of the preferred network solution and whether the estimated unserved energy at risk could be cost effectively reduced. A cost benefit assessment of demand management options has shown that non-network alternatives would not be cost effective due to the magnitude of the load reduction required.

In particular, a demand management assessment into reducing the risk of unserved energy from the 132 kV feeders showed that non-network alternatives cannot cost-effectively address the risk, compared to the two network options outlined above. This results is driven primarily by the significant amount of unserved energy that each network option allows to be avoided, compared to base case, and is detailed further in the separate notice released in accordance with clause 5.17.4(d) of the NER.[7]

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.

[7] Ausgrid notes that as part of its recently published regulatory proposal for the 2019-24 regulatory control period, it states that a Non-Network Options Report ('NNOR') will be published as part of the demand management engagement process associated with this RIT-D (see: Ausgrid, *Proposal for the 2019-24 Regulatory Control Period*, Attachment 5.14.2, p. 28). Since the regulatory proposal was finalised and submitted to the AER, Ausgrid has further assessed the capability of non-network solutions to form a credible option, or form a significant part of a credible option, for this RIT-D and has decided that they cannot. Ausgrid has consequently released a non-network screening notice in-place of a NNOR, in accordance with NER clause 5.17.4(c), which sets out the methodologies and assumptions used in reaching this conclusion.

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.

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 activates 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 2019 to 2039. 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 taking into account:

- 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 relative to the base case, and hence the expected operating and 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 options, as illustrated in section 5.1.

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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 Market benefits are expected from reduced involuntary load shedding and avoided unrelated distribution network expenditure

Ausgrid considers that the only relevant categories of market benefits prescribed under the NER for this RIT-D relate to changes in involuntary load shedding as well as changes in the timing of unrelated expenditure.

The approaches and assumptions Ausgrid has made to estimating valuing reductions in involuntary load shedding are outlined in section 4.3.1 below. A discussion of why avoided unrelated distribution network expenditure is also relevant for Option 1, but has not been estimated, as it is not material to identification of therefore option, is provided in section 4.3.2 below.

Appendix C outlines the categories of market benefit that Ausgrid considers are not material for this particular RIT-D.

4.3.1 Reduced involuntary load shedding

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 a proxy to evaluate the economic impact of unserved energy on customers under the RIT-D.

Ausgrid has applied a central VCR estimate of $40/kWh, which has been derived from the 2014 AEMO VCR estimates.[10] In particular, Ausgrid has escalated the AEMO estimate to dollars of the day and weighted the AEMO estimates according to the make-up of the specific load considered.

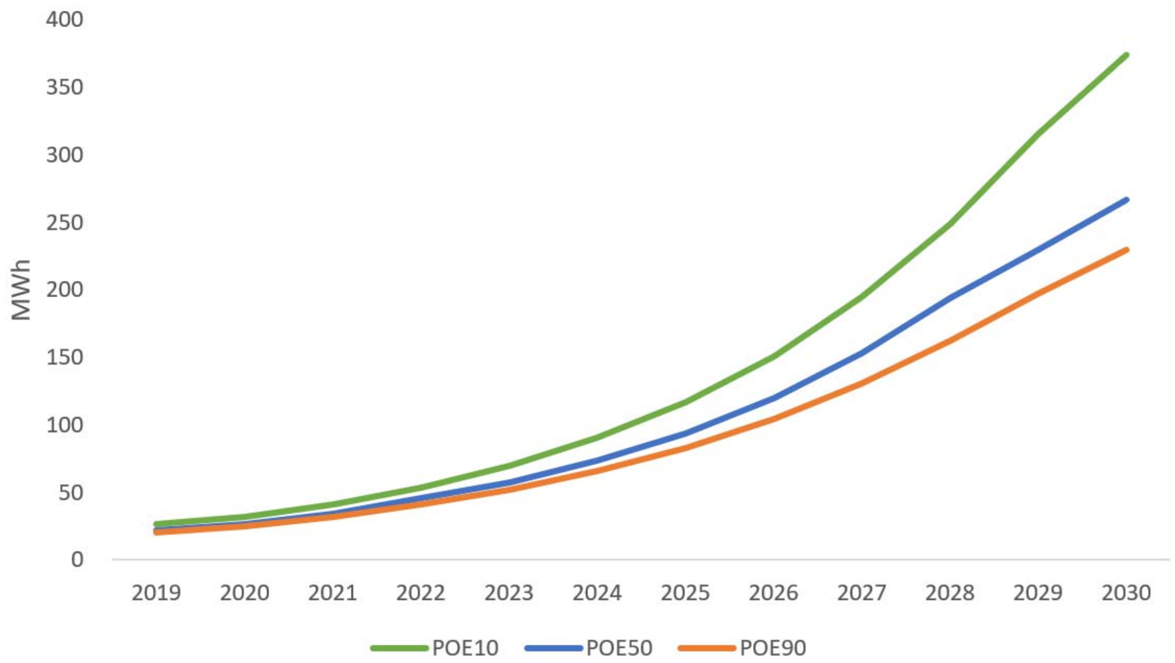
We have also investigated the effect of assuming both a lower and higher underlying VCR estimate. The lower sensitivity has been derived by reducing the AEMO-derived estimate by 30 per cent, consistent with the AEMO-stated level of confidence in its estimates, and results in an estimate of $28/kWh.[11] The higher sensitivity involves applying a VCR of $90/kWh, consistent with the recent Independent Pricing and Regulatory Tribunal (IPART) review of the transmission reliability standards for Inner Sydney, as well as the recently finalised Powering Sydney's Future RIT-T.[12]

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 percent probability of exceedance ('POE50', as well as a low forecast using the POE90 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 none no credible option is commissioned, ie, it reflects both the underlying demand forecasts and the assumed failure rates associated with keeping assets in service.

[10] AEMO, *Value of Customer Reliability Review*, September 2014, Final Report.
[11] AEMO, *Value of Customer Reliability Review*, September 2014, Final Report, p. 31.
[12] 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 4.1 – Assumed level of USE under each of the three demand forecasts



Ausgrid has capped the level of USE under each of these assumed demand forecasts at the value in the tenth year for all remaining years in the assessment period. Since the base case reflects a 'do nothing' approach, in which the reliability standard is breached (and which is therefore unrealistic), Ausgrid considers it appropriate to cap the level of USE at the level reached after ten years, since it is considered particularly uncertain after this. This also avoids a situation where an exponential increase in USE in later years[13] dwarfs other market benefits and skews the results,[14] and does not affect identification of the preferred option at all.

4.3.2 Avoiding the need for unrelated network expenditure

Under Option 1, where new feeders go via Cremorne Junction site, the installation of new feeders to connect to the future Cremorne Junction zone substation is avoided. These feeders are required under both the base case and Option 2 at some point in the future and so, their avoidance represents a market benefit attributable to Option 1. The benefit for Option 1 of this avoided expenditure should be calculated as the difference in the present value of the capital expenditure between Option 1 and the base case.

Ausgrid has however not estimated this benefit for Option 1 as it is not material to the identification of the preferred option (as outlined in section 5 below). In particular, Option 1 is strongly preferred over Option 2 on account of the benefit associated with avoided unserved energy and so estimating the benefit from deferred unrelated network expenditure would just add to this conclusion. In addition, the timing and cost of this unrelated network expenditure is uncertain at this point in time.

[13] An exponential increase in USE results from assumptions that failure rates increase exponentially with asset age. 'Capping' the USE level recognises that in reality action would be taken before this occurred.

[14] Ausgrid notes that this approach was commented on and supported by Dr Darryl Biggar in his recent review of the modelling undertaken for the Powering Sydney's Future RIT-T. See: Biggar, D., *An Assessment of the Modelling Conduced by TransGrid and Ausgrid for the "Powering Sydney's Future" Program*, May 2017, available at: https://www.aer.gov.au/system/files/Biggar%2C%20Darryl%20-%20An%20assessment%20of%20the%20modelling%20conducted%20by%20TransGrid%20and%20Ausgrid%20for%20the%20%20Powering%20Sydney%20s%20Future%20%20program%20-%20May%202017.pdf

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

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:

- 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;
- 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 market benefits.

A summary of the key variables in each scenario is provided in the table below.

Table 4.1 – Summary of the three scenarios investigated

Variable	Scenario 1 – baseline	Scenario 2 – low benefits	Scenario 3 – high benefits
Demand	POE50	POE90	POE10
VCR	$40/kWh (Derived from the AEMO VCR estimates)	$28/kWh (30 per cent lower than the central, AEMO-derived estimate)	$90/kWh (Consistent with the recent IPART review of transmission reliability standards for this area)
Commercial 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 is 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 summarises the results of the NPV analysis, including the sensitivity analysis undertaken. All credible options assessed as part of this RIT-D have been compared against a 'business as usual' base case.

5.1 Gross market benefits estimated 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 economic benefits of each credible option relative to the base case, $m 2017/18

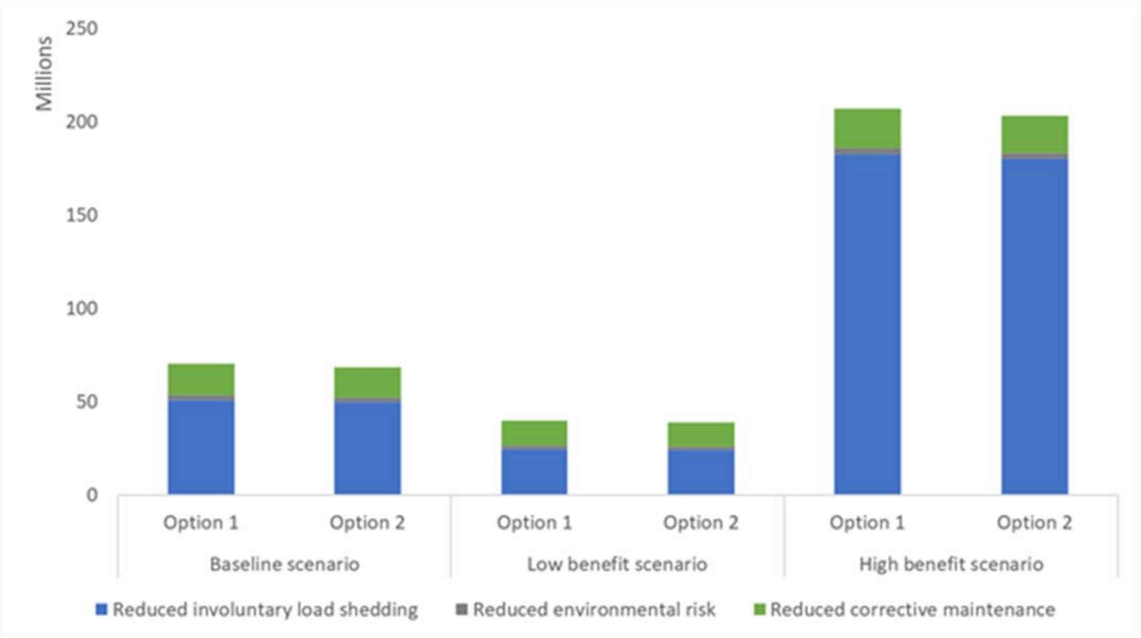
Option	Baseline scenario	Low benefit scenario	High benefit scenario	Weighted benefits
Scenario weighting	50%	25%	25%	
Option 1	70.2	40.1	207.0	96.9
Option 2	68.5	38.8	203.7	94.9

The figure below provides a breakdown of all benefits relating to each credible option. For clarity, we have combined in this chart with the categories of 'market benefit' (ie, reduced involuntary load shedding and avoiding unrelated network expenditure) with avoided corrective maintenance cost benefits (ie, reduced unplanned corrective maintenance when assets fail and reduced operating costs associated with safety and environmental costs).

Both options are found to have essentially the same overall benefit. This is driven by the fact that both options are assumed to be commisioned a year apart and so avoid similar levels of expected unserved energy and corrective maintenance costs. Option 1 has marginally higher benefits than Option 2 on account of it being commisioned a year earlier.

The primary benefit is estimated to be avoided unserved energy for both options on account of the increasing likelihood of failure of the assets in question, which are nearing the end of their technical lives.

Figure 5.1 – Breakdown of gross economic benefits of each credible option relative to the base case



5.2 Estimated costs for each credible option

The table below summarises the costs of each credible option relative to the base in present value terms. The cost is the sum of the project capital costs and the operating costs associated with running and maintaining the new cables.

The cost of each option has been calculated for each of the three reasonable scenarios, in accordance with the approaches set out in Section **4.4.**

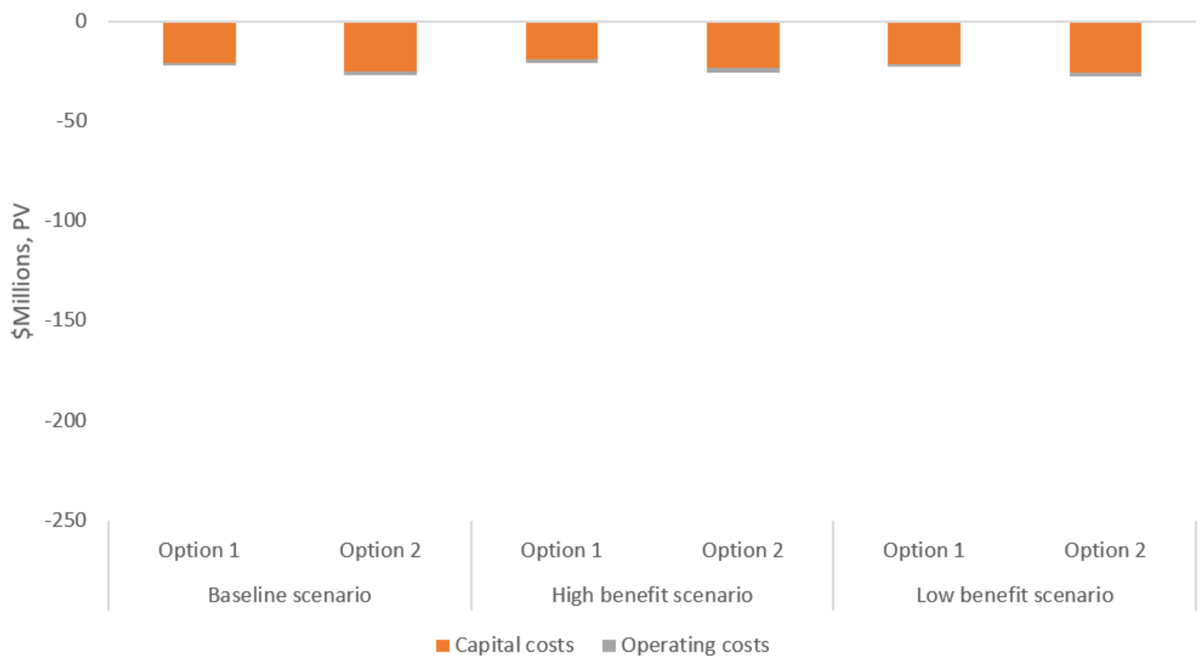
Table 5.2 – Present value of costs of each credible option relative to the base case, $m 2017/18

Option	Baseline scenario	Low benefit scenario	High benefit scenario	Weighted costs
Scenario weighting	50%	25%	25%	
Option 1	-22.3	-23.0	-20.9	-22.1
Option 2	-27.1	-27.5	-25.8	-26.9

The figure below provides a breakdown of costs relating to each credible option. Capital costs are the determining factor for the ranking of the credible options considered.

Under all scenarios, Option 1 involves the lowest capital cost due to it requiring approximately two fewer feeder kilometres. Not only does this result in fewer materials in terms of actual cables, but also the materials associated with facilitating the use of the feeders. For instance, by reducing the length of the feeder, there is a commensurate decrease in the need for other infrastructure such as joints and bays.

Figure 5.2 – Breakdown of gross costs of each credible option relative to the base case



5.3 Net present value assessment outcomes

The table below summarises the net market benefit in NPV terms for each credible option under each scenario. The net market benefit is the gross market benefit (as set out in Table 5.1) minus the cost of each option (as set out in Table 5.2), all in present value terms.

Overall, Option 1 exhibits the highest estimated net market benefit, which is primarily driven by it having the lowest capital costs out of the three credible options considered.

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

Option	Capital costs	Operating costs	Avoided costs	USE benefits	Weighted NPV	Ranking
Option 1	-20.7	-1.4	19.6	77.3	74.8	1
Option 2	-25.1	-1.8	18.8	76.1	68.0	2

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 the credible option

Ausgrid has estimated the optimal timing for each option based on the year in which the NPV of each option is maximised. This process was undertaken for both the baseline set of assumptions and also a range of alternative assumptions for key variables.

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

- a 25 per cent increase/decrease in the assumed network capital costs;
- alternative forecasts of maximum demand growth, based on POE10 (high) and POE90 (low);
- a lower VCR ($28/kWh) and a higher 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 commissioning year for each option, under a range of alternative assumptions. They illustrate that for Option 1, the optimal commissioning date is found to be in 2020/21 for almost all of the sensitivities investigated (with the exception of a low VCR, 25 per cent higher capital costs and a high discount rate). They also illustrate that 2021/22 is the optimal trigger year for Option 2.

Figure 5.3 – Option 1's distribution of optimal project commissioning years under each sensitivity

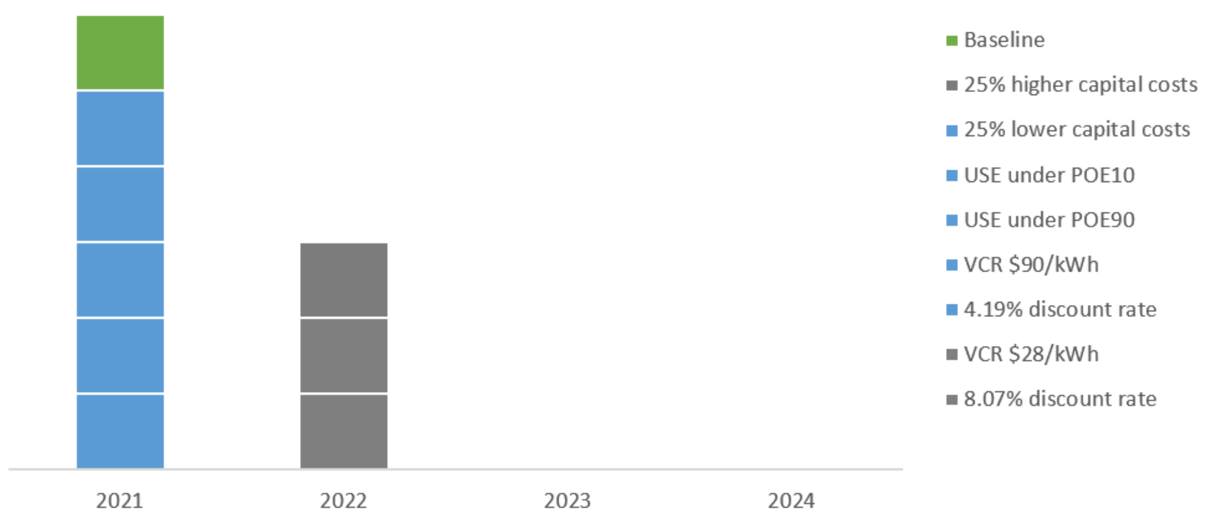
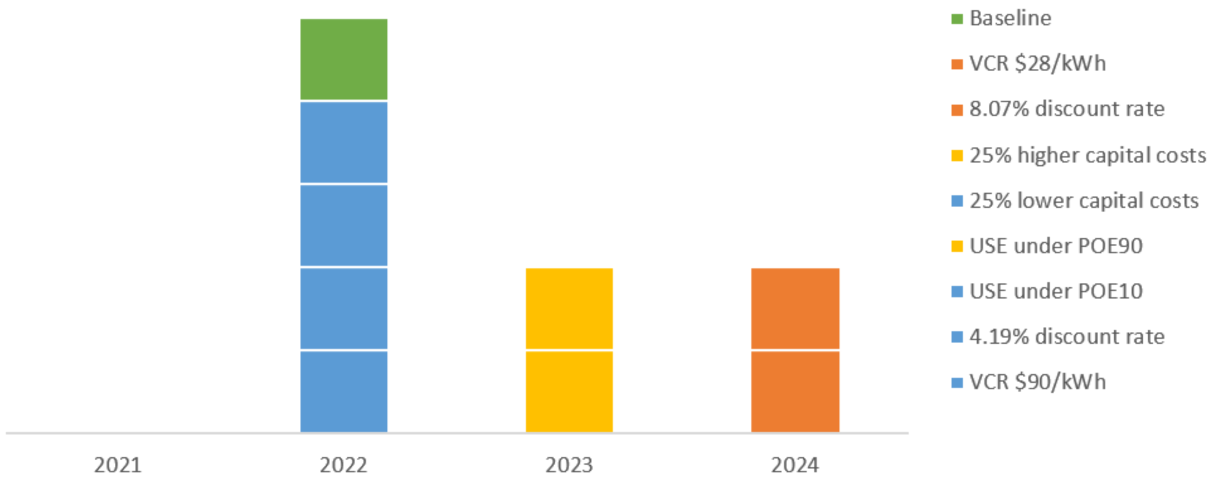


Figure 5.4 – Option 2's distribution of optimal project commissioning years under each sensitivity



5.4.2 Step 2 – Sensitivity of the overall net market benefit

Ausgrid has also conducted sensitivity analysis on the overall NPV of the net market benefit, based on the assumption option timing established in step 1.

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

- a 25 per cent increase/decrease in the assumed network capital costs;
- alternative forecasts of maximum demand growth, based on POE10 (high) and POE90 (low);
- a lower VCR ($28/kWh) and a higher 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. The table below presents the results of these sensitivity tests for option 1 and option 2 respectively. Option 1 is found to be the preferred option across all sensitivities investigated.

Table 5.4 – Sensitivity testing results, $m 2017/18

Sensitivity	Option 1	Option 2
Baseline	**47.9**	41.5
25 per cent higher capital cost	**42.7**	35.1
25 per cent lower capital cost	**53.2**	47.8
Unserved energy under POE10	**61.7**	55.1
Unserved energy under POE 90	**40.4**	34.0
VCR $90/kWh	**111.6**	104.1
VCR $28/kWh	**32.7**	26.5
4.19 per cent discount rate	**67.1**	60.5
8.07 per cent discount rate	**33.7**	27.5

6 Proposed preferred option

Option 1 has been found to be the preferred option, which satisfies the RIT-D. It involves the replacement of the two existing feeders from Castle Cove to Mosman using two new installations at the Willoughby STS. Specifically, this option involves the installation of two new 132kV feeders from Willoughby STS to Mosman zone substation. These new feeders will be routed to Mosman via the proposed Cremorne Junction zone substation site.

The scope of the project includes:

- works at Willoughby STS and Mosman zone substation to facilitate new 132kV feeder connections;
- installation of a dual circuit 132kV feeder approximately 7km in length between Willoughby STS and Mosman zone substation; and
- control and protection communication upgrades at the Willoughby STS and Mosman zone substation to accommodate the new feeders.

The estimated capital cost of this option is approximately $28.9 million. Ausgrid assumes that the necessary construction to install the new feeders would commence in 2018/19 and end in 2021/22. One the new installation is complete, operating costs are expected to be $150,000 per annum (around 0.5 per cent of capital expenditure).

Ausgrid considers that this DPAR, and the accompanying detailed analysis, identify Option 1 as the preferred option and that this satisfies the RIT-D. Ausgrid is the proponent for Option 1.

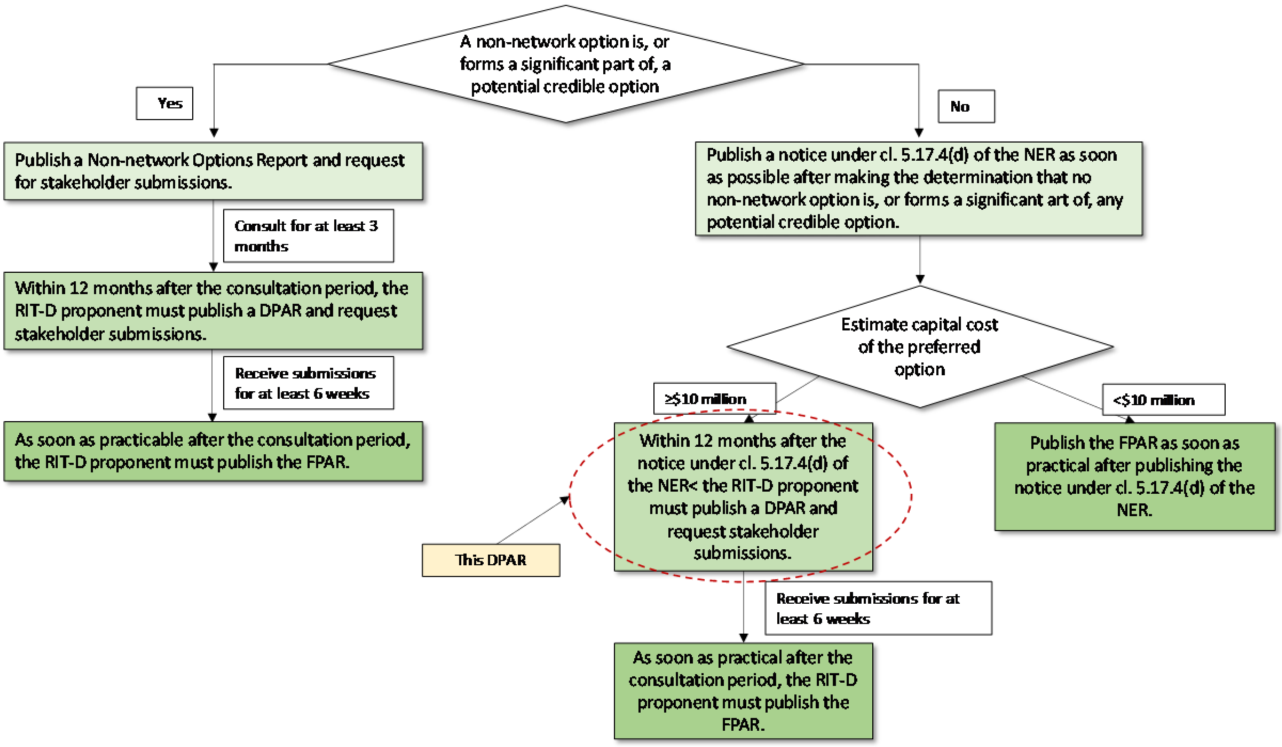
Appenidx A – Checklist of compliance clauses

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 107.

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
	(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	5.2
	(7) a detailed description of the methodologies used in quantifying each class of cost and market benefit	4
	(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 C
	(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.	0

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 – 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; and
- electrical energy losses.

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 C.1 – 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 for replacement. Consequently, Ausgrid has not attempted to estimate any benefits from changes in load transfer capacity and embedded generators.
Option value	Option values arise where there is uncertainty regarding future outcomes, the information that is available in the future is likely to change, and the credible options considered have sufficiently flexible to respond to that change. Ausgrid notes that none of the credible options assessed involve stages or any other flexibility and so we do not consider that option value is relevant. Ausgrid notes that Option 1 does allow for lower connection costs for a future Cremorne Junction zone substation than the base case and Option 2 if/when that zone substation is built. This is benefit of Option 1 but has not been estimated as part of the assessment due to the uncertainty involved, as well as the fact that it would not affect identification of the preferred option, as outlined in section 4.3.2 above.
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.

Appendix D – Additional detail on the assessment methodology

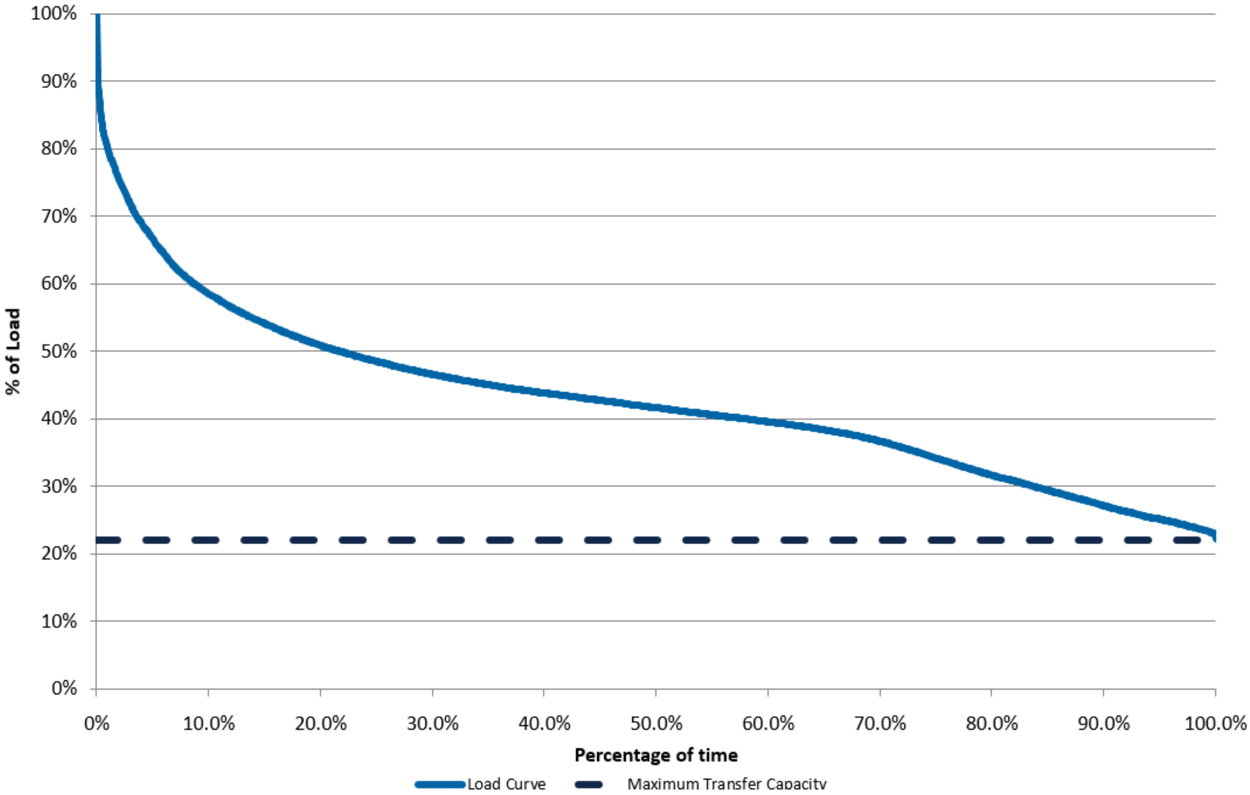
This appendix presents additional detail on the supply restoration assumptions and probability of failure assumptions made by Ausgrid.

D.1 Characteric load duration curves

The load duration curve for the Mosman zone substation is presented in Figure D.1 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 into the future and therefore the load duration curves will maintain their characteristic shape regardless of the zone substation supplying the existing load at Mosman.

Figure D.1 – Load duration curve for Mosman



Supply restoration assumptions

Table D.1 – Supply restoration assumptions

Equipment outage	Action	Outage duration
Fluid filled cable failure	Repair The cable is repaired on site.	7.0 weeks
Fluid filled cable third party damage	Repair The cable is repaired on site. Additional time is typically required to repair third party damage.	5.5 weeks
Fluid filled cable corrective action	Repair 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. 1.06 weeks

Probability of failure

Ausgrid has adopted probability models to estimate expected failure of different network assets. A summary of the models adopted and the key parameters used are summarised in the table below.

Table D.2 – Summary of failure probability models used to estimate failure probability

Network asset type	Failure probability model	Key parameters
Underground cables	Crow-AMSAA model	Cumulative number of failures per km Age of cable at failure in years Measure of the failure rate

Underground cables

The Crow-AMSAA model is used to determine the probability of failure and unavailability for underground cables. Crow-AMSAA models are fitted for gas pressure, HSL and XLPE cables.

The Crow-AMSAA model can be used to evaluate probability of failure for repairable systems. As a result, it can be used to model a cable section that has failed and has been repaired multiple times over its lifetime. The model is also capable of handling a mixture of failure modes. Events affecting Ausgrid's underground sub-transmission cables are classified as corrective action, failure or third-party damage.

An analysis is undertaken of failure data to ascertain the age of the cable at the time of each event. A log-log plot of cumulative failures (per km) versus cumulative time (i.e. age in years) is produced and a line of best fit determined. The resulting log-log plot is linear and the line of best fit can be described by Equation 1.

Equation 1

$$z(T) = \lambda\beta T^{\beta-1}$$

Where:

$z(T)$ is the current failure intensity at time T (normalised per km length)
T is the cumulative time (i.e. age of the cable at failure, in years)
β is the shape parameter
λ is the scale parameter

The above process is carried out for corrective actions, failures and third party damage for gas pressure, HSL and XLPE cables.
Table D.3 shows the modelled Cow-AMSAA parameters for each cable type.

Table D.3 – Underground cable parameters

Feeder	Type	β factor	λ factor	MTTR* (weeks)
9Y7/2	Corrective action	4.86	1.93E-08	1.06
9Y7/2	Breakdowns	5.83	1.35E-11	7.0
9Y7/2	Third party damage	1.48	8.78E-05	5.5
9Y9/2	Corrective action	5.24	1.93E-08	1.06
9Y9/2	Breakdowns	6.28	1.35E-11	7.0
9Y9/2	Third party damage	1.59	8.78E-05	5.5
9P7	Corrective action	4.74	1.93E-08	1.06
9P7	Breakdowns	5.69	1.35E-11	7.0
9P7	Third party damage	1.44	8.78E-05	5.5

* Mean Time to Repair

The frequency of corrective action, failure or third party damage can then be determined by applying Equation 2 to each cable section.

Equation 2

$$f = L\lambda((T+1)^{\beta} - T^{\beta})$$

Where:

f is the frequency of failures

L is the length of the cable segment (km)

Failures and third party damage result in cables being taken out of service. Corrective actions do not typically result in cables being taken out of service. Equation 3 shows how the frequency is used to calculate unavailability for failures or third party damage.

Equation 3

$$U = \frac{f \times MTTR_{weeks}}{52 + f \times MTTR_{weeks}}$$

The total cable section unavailability is calculated taking the union of the failure and third-party damage unavailabilities as shown in Equation 4. If a feeder consists of multiple cable sections, the feeder unavailability is calculated by taking the union all the respective section unavailabilities.

Equation 4

$$U_{total} = U_{failure} \cup U_{TPD}$$

Figure 3 in section 2.3.2 shows unavailability plotted on a logarithmic scale when the above equations are applied to 10km cables aged 0 – 100 years. This model is also based on the assumption that the condition of a cable is dependent upon its age. The Crow-AMSAA model shows that the availability of gas pressure cables is expected to decline if the cables are retained past an age of 50.

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