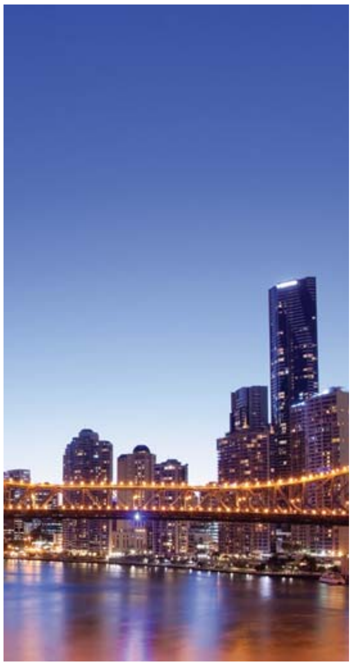


Strategic Options Evaluation – Brunswick Area

CitiPower

19 June 2019

Contents

Overview

The Brunswick area of CitiPower's network is supplied by Brunswick Terminal Substation (BTS) and West Melbourne Terminal Substation (WMTS). There are five Zone Substations (ZS) that are supplied by BTS and WMTS, which then distribute power throughout the Brunswick local area.

Concerns relating to two of the ZSs in the area, Brunswick (BK) and Fitzroy (F), have triggered a strategic options evaluation for the entire Brunswick area. The BK and F ZSs have ageing assets that are subject to deteriorating health, and present an increasing risk to the operation of the network as well as safety of workers and the community.

The identified need is to efficiently meet forecast consumer demand for electrical power throughout the Brunswick area. The key issues for the Brunswick area are summarised as follows:

- **Assets approaching end-of-life:** Both primary plant and general site infrastructure is approaching end-of-life and have high probability-of-failure (PoF) that will continue to increase.
- **Disruptive failures:** A disruptive failure of any of these assets presents a significant risk to supply availability to inner suburbs of Melbourne city.

  Catastrophic failures: Of particular concern, is that assets of this vintage are relatively susceptible to catastrophic failure. A catastrophic failure of any of the assets can result in loss of supply to the inner suburbs of the Brunswick area. The assets, being oil-filled plant items, are relatively susceptible to failing explosively compared with modern equivalents, which increases the safety risks associated with them. The increased maintenance burden associated with these sites further increases the exposure of maintenance personnel to safety risks associated with catastrophic failures.
- **Construction constraints:** The BK and F substations were constructed nearly eighty years ago, prior to the development of contemporary design standards, and the civil infrastructure on site is also deteriorating in condition. These sites are located in Melbourne's inner suburbs and are space constrained, both internally and in relation to access surrounding the sites. This constrains the ability for piecemeal construction or rebuilding the sites whilst they remain in operation; and attract relatively higher costs, and safety and operational risks.
- **Good electricity industry practice:** The BK and F substations operate using a 22 / 6.6 kV voltage philosophy, which is an outdated and sub-optimal industry practice. Piecemeal renewal of assets at end-of-life (if viable) would extend these issues over the service life of the new assets (over 50 years).

Eight options have been evaluated:

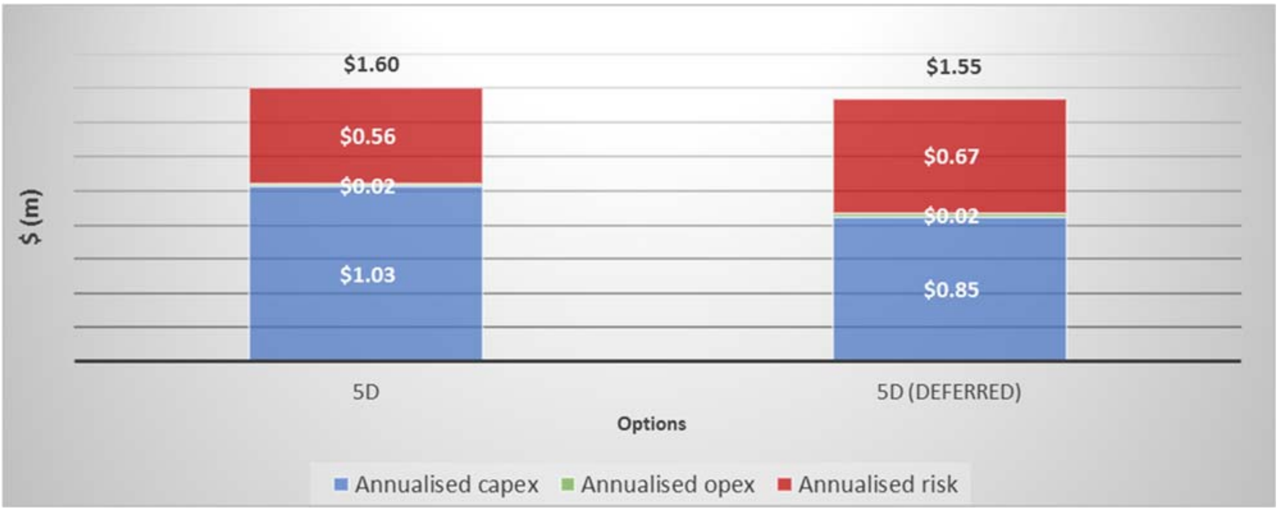
- Option 1: Continued maintenance and monitoring
- Option 2: Non-network solutions
- Option 3: Life extension of existing assets (refurbishment)
- Option 4: Replacement of existing assets (in-situ)
- Option 5a to 5d: Retirement of existing assets (and transfer of load to nearby substations)

The evaluation demonstrates that Option 5d (Offload ZS F to ZS CW and ZS BK to ZS WB at 66/11 kV) is the most prudent and efficient solution to manage the issues summarised above. This assessment is based on the evaluation of Direct Cost (capex + opex) and Risk Cost, and comparative advantages and disadvantages. The implementation plan for the preferred option shows that the optimal Net Present Value (NPV) occurs when implementation of the preferred option is deferred to 2023.

Option 5d Advantages	
✓	It is the lowest total cost solution.
✓	It addresses the risk profile associated with Option 1 (following implementation in 2023).
✓	Redevelopment and future use/sale of two offloaded sites (ZS BK and ZS F), plus ZS C site remains unutilised.
✓	The option reduces network security, but this risk is partially mitigated at 11 kV due to the ability to reconfigure the network to restore power.
✓	The option overcomes identified issues in relation to good electricity industry practice.

The figure below compares the annualised costs for the preferred option if implemented immediately and if deferred to an optimal implementation timing of 2023.

Deferring the investment discounts the annualised capex spend for Option 5d from $1.03 m to $0.85 m based on a real discount rate of 3.06%, equivalent to CitiPower's real weighted average cost of capital (WACC). This requires continuing with Option 1 (continued maintenance and monitoring) and accumulating associated risk through to 2022. The total annualised cost for implementing the optimal solution in 2023 is $1.55 m, versus $1.60 m for implementing the option now.



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1. Background

1.1 Purpose

The Brunswick area of CitiPower's network is supplied by Brunswick Terminal Substation (BTS) and West Melbourne Terminal Substation (WMTS). There are five Zone Substations (ZS) that are supplied by BTS and WMTS, which then distribute power throughout the Brunswick local area.

Concerns relating to two of the ZSs in the area, Brunswick (BK) and Fitzroy (F), have triggered a strategic options evaluation for the Brunswick area. The BK and F ZSs have ageing assets that are subject to deteriorating health, and present an increasing risk to the operation of the network as well as safety of workers and the community. The increasing risk profile warrants investigation to identify and evaluate options for the management of these assets.

The purpose of this document is to summarise the strategic options evaluation that has been undertaken, and outline the preferred option to meet forecast consumer demand for electrical power throughout the Brunswick area.

1.2 Background

GHD has been engaged by CitiPower to undertake this strategic options evaluation for the Brunswick area. The report has been developed collaboratively with relevant personnel from CitiPower.

GHD personnel worked closely with personnel from CitiPower's Network Planning group, to understand issues relevant to the evaluation. GHD met with personnel from Network Planning, Asset Management, Network Operations and Network Services to gain a stronger understanding of the issues.

Two workshops were held with relevant representatives participating from each of the above groups:

- Issues Workshop: The first workshop focussed on understanding the issues associated with the assets of concern. Workshop participants produced a collective definition of why the risk profile of the assets warrants a detailed investigation and options evaluation.
- Options Workshop: The second workshop focussed on identifying the full range of potential options to meet forecast consumer demand for electrical power throughout the Brunswick area. Workshop participants produced a collective definition of the credible options that should be investigated in detail.

Following the on-site explorative activities GHD sourced information from CitiPower required to undertake detailed investigation and analysis, and develop the strategic options evaluation.

1.3 Scope

The scope of this report relates to ZSs BK and F, and includes:

- Background (Section 1): Description of the historical development and current status of the Brunswick area in general, and how this compares to "good electricity industry practice".
- Identified need (Section 2): Detailed articulation of the issues and risk profile associated with the assets of concern (initially defined through the Issues Workshop outlined in Section 1.2).

- Options (Section 3): Detailed investigation into the credible options to meet forecast consumer demand for electrical power throughout the Brunswick area. These were initially established through the Options Workshop outlined in Section 1.2 as follows:
  - Continued maintenance and monitoring (Section 3.1)
  - Non-network solutions (Section 3.2)
  - Life extension of existing assets (Section 3.3)
  - Replacement of existing assets (in-situ) (Section 3.4)
  - Retirement of existing assets (Section 3.5)
- Preferred Option (Section 4): Comparative evaluation of options to identify the preferred option.

1.4 Assumptions

The following assumptions have been applied in developing the options and their evaluation (based on the collaborative process described in Section 1.2):

- The distribution networks downstream of ZSs BK and F operate at 6.6 kV. We have assumed that these assets are 11 kV rated and will not need to be replaced in the options where the operating voltage is increased to 11 kV. Note that three of the eight BK feeders already operate at 11 kV.
- Distribution Substations (DS) are an exception to the above assumption. We understand that a portion of the DSs operating at 6.6 kV are “dual-wound” meaning they are “11 kV ready”, whereas a portion that are not dual-wound will need to be replaced where the operating voltage is increased to 11 kV. A survey has been undertaken of the DS population, which identified a percentage of 11 kV ready DSs.
- We understand that a related project proposed within the Brunswick area is currently undergoing a Regulatory Investment Test – Distribution (RIT-D). In carrying out our evaluation we have assumed that the preferred option from the RIT-D has been implemented i.e. we have assumed that ZS Brunswick (C) has been retired and its feeders transferred to ZS West Brunswick (WB).
- The economic analysis for the options evaluation assumes a 50 year service life for all network options (30 years for non-network – Option 2) and applies a real Weighted Average Cost of Capital (WACC) of 3.06%. This is consistent with the regulated WACC.

1.5 Brunswick electricity distribution network

1.5.1 Development of the Brunswick area

The Brunswick area is supplied by a combination of two operating voltages:

- 22 kV sub-transmission and 6.6 kV distribution: BTS supplies ZSs BK, C and Fitzroy (F) via a 22 kV sub-transmission network. These ZSs then distribute power at 6.6 kV.
- 66 kV sub-transmission and 11 kV distribution: WMTS supplies ZSs WB and Northcote (NC) via a 66 kV sub-transmission network. These ZSs then distribute power at 11 kV.

The different operating voltages are a result of evolving industry practice; where 22 kV / 6.6 kV is a historic approach. The higher operating voltages of 66 kV / 11 kV have been adopted as the modern industry approach as they provide for a more efficient supply of power to a greater population density (and associated electrical demand density). At some substations auto-transformers have been installed on individual feeders to which means some ZSs are supplying at both 6.6 kV and 11 kV.

The Brunswick area has been transitioning from low density residential (suburban) to high density residential (apartment buildings), and the outlook for the area is for this trend to continue. The Australian Energy Market Operator's (AEMO) "Transmission Connection Point Forecasts" show Brunswick as the highest growth area in Victoria, with annual growth rates of around 6%[1]. This trend suggests that a 66 kV / 11 kV operating voltage is better suited for the area than a 22 kV / 6.6 kV operating voltage philosophy.

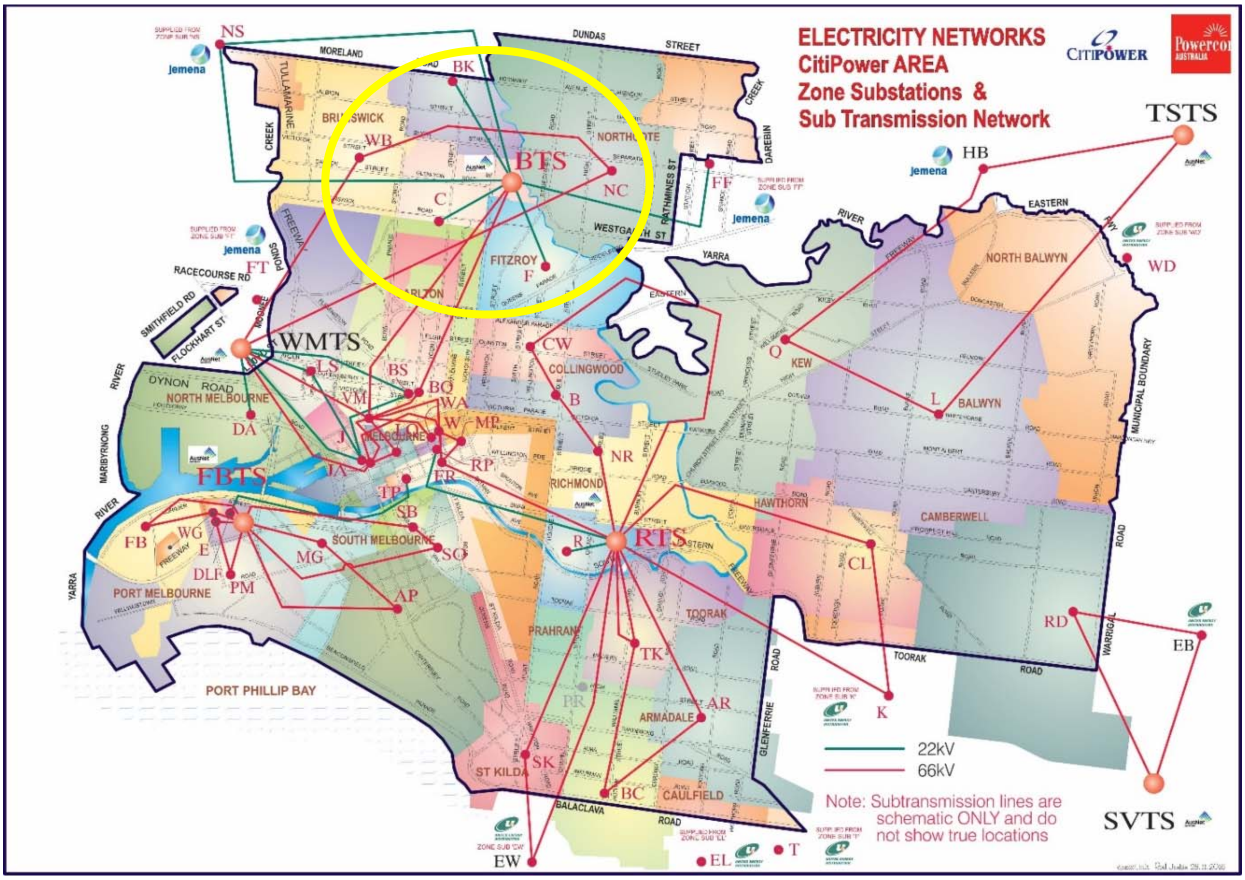
Another consequence of having two different operating voltages is that the area is supplied by two "islanded" networks which can't be operationally interconnected; this constrains the ability to reconfigure the network to restore supply during power outages (i.e. customers on the 6.6 kV network cannot be supplied by adjacent 11 kV feeders during outage events).

Practices relating to the use of 6.6 kV distribution within the National Electricity Market (NEM) is discussed in further detail in Section 1.6.

The sub-transmission network for the Brunswick area is encircled in yellow in the below map.
The delineation of the CitiPower network is based on council areas, whom were historically responsible for independently supplying their individual areas. Subsequently, ZS BK does not supply outside the CitiPower footprint although it is located just inside the geographic boundary.

[1] https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Transmission-Connection-Point-Forecasting/Victoria

Figure 1: Map of CitiPower sub-transmission network with Brunswick encircled in yellow



1.5.2 Overview of assets in Brunswick (BK) and Fitzroy (F) Zone Substations

Table 1 provides an overview of assets in ZS BK and F substations. Condition issues associated with these assets are discussed in risk profile of the assets is discussed throughout Section 2.

Table 1: Overview of ZS BK and F assets

Items	Brunswick (BK)	Fitzroy (F)
Voltage	22 kV / 6.6 kV + 11 kV	22 kV / 6.6 kV
Capacity / Max. Demand (MVA)	S: 27.2 / 14.1 W: 28.6 / 13.5	S: 24.1 / 15.0 W: 28.5 / 15.3
Transformers	3 x 10 MVA	2 x 10 MVA
Sub-transmission feeders	3	3 *
2ndary feeders	5x6.6 kV & 3x11 kV	10x6.6 kV
11 kV ready DSs	30%	30%
Capacity comments	• Demand is below firm rating (N-1).	• Demand is above firm rating (N-1).

Items	Brunswick (BK)	Fitzroy (F)
Condition comments	• Transformer No.1 is approaching end of life (68 years old)	• Transformer No.1 is deteriorating in condition (61 years old) (its pair has already conditionally failed) • The secondary switchboard is approaching end of life (78 years old)

** One of the three transformers at ZS F has been removed from service due to its high likelihood of failure and deteriorating condition.*

1.5.3 Summary of asset condition issues in Brunswick (BK) and Fitzroy (F) Zone Substations

The Brunswick (BK) and Fitzroy (F) Zone Substations were constructed nearly eighty years ago, prior to the development of contemporary design standards. In addition to the deteriorating condition of the electrical infrastructure, the civil infrastructure on site is deteriorating in condition. Primary plant at ZS BK and F are also approaching end-of-life and have high probability-of-failure (PoF) that will continue to increase (including transformers and secondary switchboards equipped with around ten individual circuit breakers).

Transformers:

- Brunswick (BK): Brunswick has three transformers – two have exceeded their nominal lifespan (one is 68 years old and one is 55 years old), and the third was installed eight years ago.

  The 68 year old transformer has reached end-of-life and has a high risk of imminent failure, and the 55 year old transformer has deteriorated in condition and is approaching end-of-life. The 8 year old transformer was installed when the other original transformer became unserviceable at around 60 years old. This transformer was of the same type (AEI) as the two deteriorating transformers that remain in service.

- Fitzroy (F): Fitzroy is a three transformer substation but has only two transformers remaining in service (one has been removed from service as its deteriorated condition means it can no longer be operationally maintained).

  Of the two remaining in service, one has exceeded its nominal lifespan (being 61 years old, versus generally accepted industry nominal lifespans of 45-55 years)[2], and the other was installed seven years ago. The 61 year old transformer has deteriorated in condition and is approaching end of economic life. The 7 year old transformer was installed when the previous transformer became unserviceable at around 55 years old. The deteriorating transformer that remains in service is of the same type (AEI) as the two transformers that are now unserviceable.

Switchboards:

- Brunswick (BK): Brunswick has an Email LC J18 switchboard that is now 55 years old.

  The switchboard has returned low insulation resistance results since 2017 and is now subject to ongoing monitoring for further deterioration. Deteriorating insulation resistance indicates that, without intervention, the switchboard will continue to deteriorate until an arc-fault occurs. Switchboards of this vintage do not meet modern design standards and are not arc fault contained or vented. This means that an arc-fault is more likely to result in explosive failure than would be the case with modern arc

[2] CitiPower nominates an average economic life of 55 years for ground mounted outdoor power transformers within its Category Analysis RIN response (*D18-60142 CitiPower 2017 – RIN response - Category Analysis - Consolidated – Public.xls*)

suppressed switchboards. As such, in addition to operational risks, the deteriorating insulation resistance presents a significant safety risk to personnel entering the substation.

In addition to the above, the switchboard has asbestos filled secondary cable trunks. Deterioration in the mechanical protection has exposed the asbestos, which has been temporarily secured by taping over the flexible cable trunks.

Maintenance personnel enter the substation more often than is typical for such substations due the general deterioration of site infrastructure and ongoing testing and monitoring of the switchboard.

- Fitzroy (F): Fitzroy has a Reyrolle Type C switchboard that is now 78 years old.

  The circuit breakers are not equipped with automatic spring rewind, which means that operators are required to attend site each time a circuit breaker operates. The operators must manually charge the closing spring of the circuit breakers to restore supply following an operation. This also results in extended outage times for customers supplied from ZS F.

  The switchboard is a bitumen-compound filled type and is visibly deteriorating in condition. As with Brunswick, switchboards of this vintage do not meet modern design standards and are not arc fault contained or vented. This means that an arc-fault is more likely to result in explosive failure than would be the case with modern arc suppressed switchboards. As such, in addition to operational risks, the deteriorating condition presents a significant safety risk to personnel entering the substation.

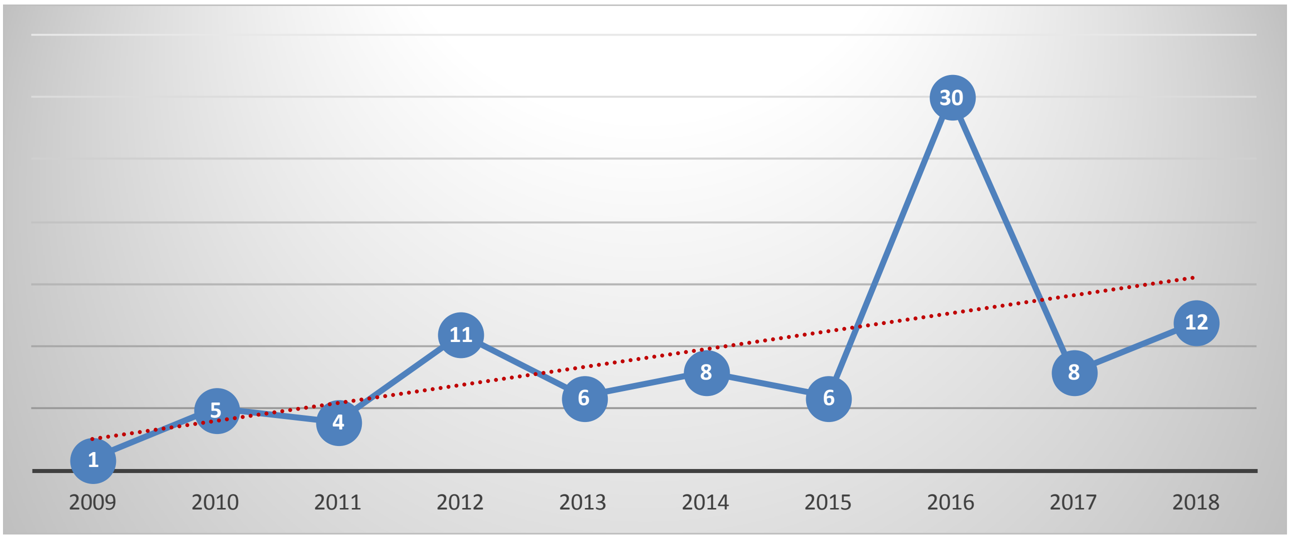
  Maintenance personnel are now required to enter the substation more often due the general deterioration of site infrastructure and requirement to manually operate the circuit breakers.

General site infrastructure:

The observable condition issues are also apparent in defect rates for equipment at ZS BK and ZS F. Figure 2 demonstrates an increasing trend in defect rates. This trend is expected to continue despite a major maintenance intervention in 2016 (in 2018 rates have already increased above pre-2016 levels). The defects are spread across all site infrastructure. The increasing trend in defect rates illustrates the increasing risk profile for ZS BK and ZSF, which is not confined to the advanced deterioration of the transformers and switchboards.

The deterioration of site infrastructure presents operational risks and maintenance costs. Of particular concern is that the increased maintenance burden exposes personnel to safety risks associated with being in the vicinity of the transformers and switchboards which are at heightened risk of catastrophic failure (and do not meet modern design standards to safeguard against explosive failure).

Figure 2: Number of defects at ZS BK and ZS F



1.6 Overview of 6.6 kV distribution trends in the NEM

The NEM operates using a power system model of bulk base-load generation (coal fired), peak demand generation (gas fired), and distributed renewable generation. All of these generation sources are developed remote from urban areas, with power then transmitted and distributed to consumers. High voltages are used to transmit and distribute electricity as this is more efficient, both in terms of reduced losses and a lower quantum of assets required to transfer power.

A notable exception to the above is embedded rooftop solar photovoltaic (SPV) panels. Rooftop SPV reduces the demand seen by the network, but does not (and will not in the foreseeable future) negate the need for electricity transmission and distribution. Hence, transmission and distribution will continue to be required as the NEM transitions away from bulk coal fired generation to distributed renewable generation and storage.

The NEM model described above is substantially different to when Australia's electricity networks were first established. Historically, electricity was supplied by local small-scale fossil-fuel fired generators, which was then distributed throughout local council areas. Demand density at this time was incomparably lower than it is today, and therefore, lower distribution voltages were an efficient means of power distribution.

Hence, CitiPower's distribution network was established at 6.6 kV, which was standard practice at the time of development. As generation sources were removed from urban centres, 22 kV sub-transmission was installed to transfer power to local areas.

As maximum demand and demand density increased, transmission and distribution voltages have also increased throughout the NEM to facilitate more efficient electricity supply. Throughout this period, the majority of CitiPower's network has been converted from 22/6.6 kV to 66/11 kV, which is standard practice across the NEM for central city areas.

CitiPower's Brunswick and Port Melbourne areas are the last remaining localities continuing to operate using the 6.6 kV distribution voltage. A large proportion of these assets were installed over 80 years ago or more, have exceeded their nominal lifespan, and are deteriorating in condition.

The 6.6 kV assets are comprised of outdated technologies and installation practices that are more prone to failure e.g. paper insulated cables and directly buried underground than modern equivalent assets. The increased risk of failure is compounded by the 6.6 kV networks being “islanded” from the adjacent 11 kV network. The islanding means that customers on the 6.6 kV network cannot be supplied by adjacent 11 kV feeders during outage events.

The issues described above are not unique to CitiPower. Distribution Network Service Providers (DNSP) throughout the NEM have been replacing their 6.6 kV networks with modern equivalent networks as they reach end-of-life (e.g. 11 kV XLPE insulation cable installed conduit and overlayed with protection tape). Figure 3 shows the progressive retirement of 6.6 kV assets at DNSPs throughout the NEM.

Figure 3 Progressive retirement of 6.6 kV (or 5 kV) distribution assets across the NEM

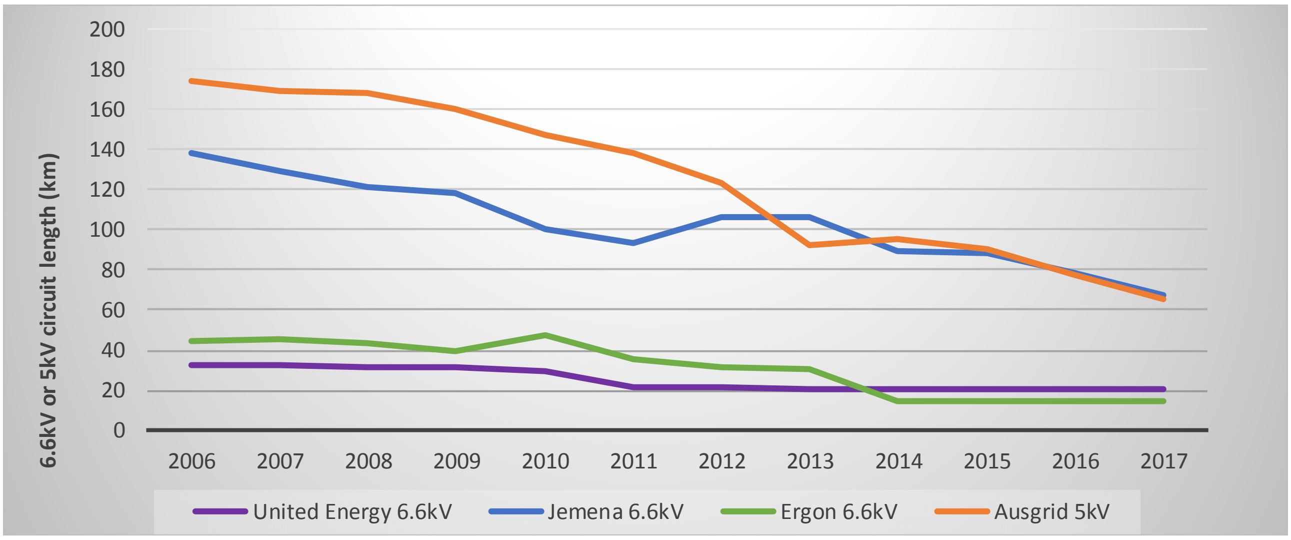
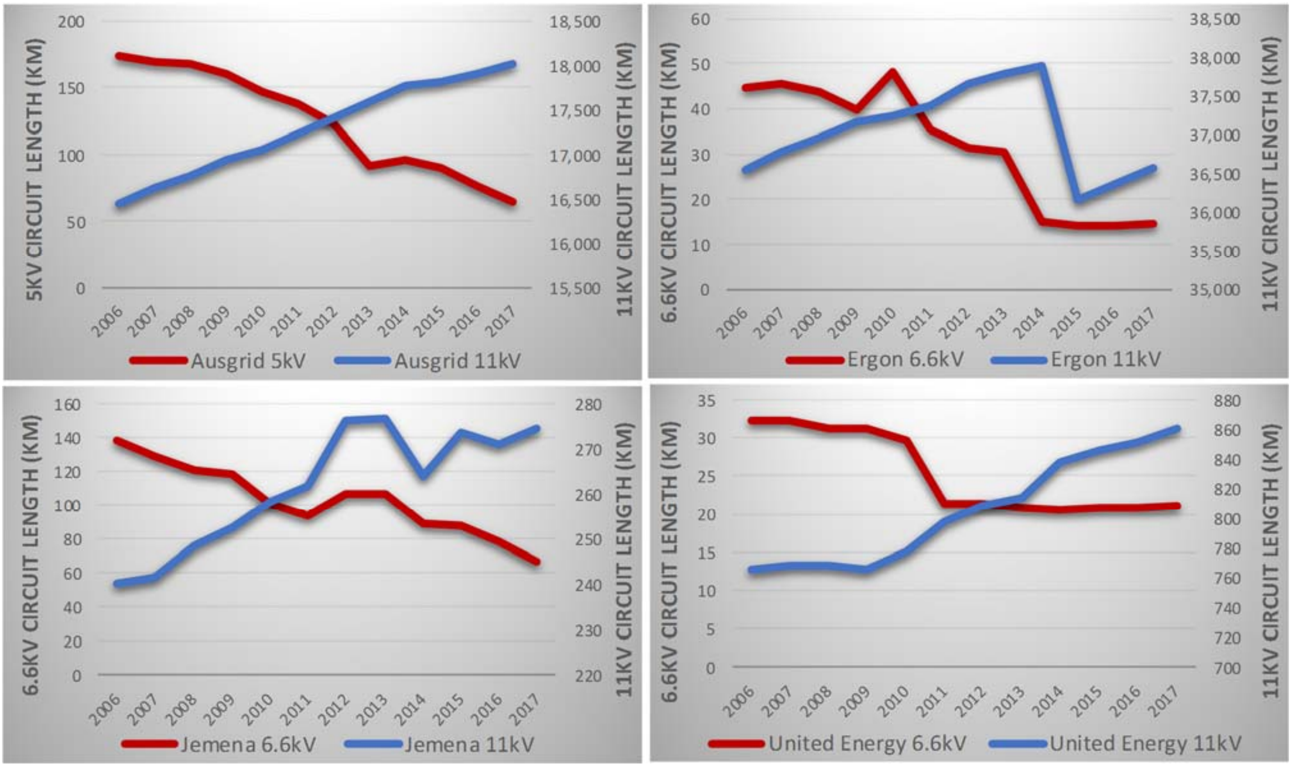


Figure 4 compares quantities of 6.6 kV versus 11 kV assets. It indicates that DNSPs are generally retiring their 6.6 kV assets and replacing them with modern equivalent 11 kV assets.

Figure 4: Volumes of 6.6 kV (or 5kV) vs. 11 kV distribution assets across the NEM



1.7 "Good Electricity Industry Practice"

The National Electricity Rules (NER) define 'Good Electricity Industry Practice' as shown below. In effect, the definition suggests that CitiPower can look to peer Network Service Provider (NSP) practices as a baseline indicator for good practice.

> ***good electricity industry practice***
>
> The exercise of that degree of skill, diligence, prudence and foresight that reasonably would be expected from a significant proportion of operators of *facilities* forming part of the *power system* for the *generation*, *transmission* or *supply* of electricity under conditions comparable to those applicable to the relevant *facility* consistent with *applicable regulatory instruments*, *reliability*, safety and environmental protection. The determination of comparable conditions is to take into account factors such as the relative size, duty, age and technological status of the relevant *facility* and the *applicable regulatory instruments*.

(Source: National Electricity Rules Version 111)

In the context of a strategic options evaluation for the Brunswick area, good practice can be interpreted as follows:

- An asset's likelihood of failure increases as it deteriorates with age. These assets present an increasing risk to the operation of the network, and safety of workers and the community. An NSP would be expected to exercise skill, diligence, prudence and foresight to:

- Progressively retire such assets in view of the risk that they present;
- Where appropriate, replace non-standard and obsolete assets with modern equivalent assets of standard specifications; and
- In doing so, seek an enhanced operational and safety risk profile than originally existed through the application of efficiency frontier asset management practice.

- Specific issues in the Brunswick area relating to outdated or obsolete industry practices include:
  - As discussed in Sections 1.5.1 and 1.6, the use of 6.6 kV assets is a non-standard practice. When these networks were first established each council area used local diesel generation to supply the area; where 6.6 kV networks were established based on the diesel generator output voltage. 11 kV has since been established as standard distribution voltage as it distributes power more efficiently, using similar size assets but requiring less assets to perform the same task. CitiPower's comparable peers have been observed to be retiring their 6.6 kV assets.

    This suggests that, when the risk profile warrants retirement of 6.6 kV assets, good electricity industry practice would preference transitioning to 11 kV distribution rather than continuing with the legacy 6.6 kV distribution.

    It is understood that current projects underway will leave the Brunswick area as one of only two remaining pockets of 6.6 kV network on CitiPower's network (the other being the Port Melbourne area).
  - Bitumen-compound insulated secondary switchboards that house bulk-oil circuit breakers are obsolete, and manufacturers no longer produce or support them. Modern equivalents use vacuum or SF6 CB panels installed indoor in switch rooms at distribution voltage levels. Modern panels are designed with "arc fault" containment systems, which makes them inherently safer. They are also more efficient (cost and space), with advanced communication and measurement capabilities.

    This suggests that, when the risk profile warrants retirement of bitumen-compound and oil-filled assets, good electricity industry practice would preference transitioning to modern equivalent assets (e.g. vacuum or SF6 insulated).

2. Identified need

The identified need is to efficiently meet forecast consumer demand for electrical power throughout the Brunswick area.

2.1 Issues summary

The key issues for the Brunswick area are summarised as follows:

- **Assets approaching end-of-life:** Primary plant at ZS BK and F are approaching end-of-life[3] and have high probability-of-failure (PoF) that will continue to increase (including transformers and secondary

[3] Some of the primary plant at ZS BK and F are approaching 80 years in service.

switchboards equipped with around ten individual circuit breakers). General site infrastructure is also deteriorating in condition.

- **Disruptive failures:** A disruptive failure of any of these assets presents a significant risk to supply availability to inner suburbs of Melbourne city.
- **Catastrophic failures:** Of particular concern, is that assets of this vintage are relatively susceptible to catastrophic failure:
  - A catastrophic failure of any of the assets can result in complete loss of supply to the inner suburbs of Melbourne that are supplied by these substations. Emergency diesel generators would be required for up to three months to restore power.
  - Upon catastrophic failure, bulk-oil and bitumen-compound insulated assets are purported to be relatively susceptible to failing explosively compared with modern equivalents, which increases the safety risks associated with them.
  - A catastrophic failure of bulk-oil insulated assets will cause it to release its tank of oil, which will contaminate the land if containment systems fail (which would likely be damaged by an explosive failure).

  The increased maintenance burden associated with these sites increases the exposure of maintenance personnel to safety risks associated with catastrophic failures.
- **Construction constraints:** The BK and F substations were constructed nearly eighty years ago, prior to the development of contemporary design standards. Further, the civil infrastructure on site is deteriorating in condition. These sites are located in Melbourne's inner suburbs and are space constrained, both internally and in relation to access surrounding the sites. This constrains the ability for piecemeal construction or rebuilding the sites whilst they remain in operation; and attract relatively higher costs, and safety and operational risks.
- **Good electricity industry practice:** The BK and F substations operate using a 22 / 6.6 kV voltage philosophy, which is an outdated and sub-optimal industry practice (refer to Sections 1.5, 1.6 and 1.7). Piecemeal renewal of assets at end-of-life would extend outdated business practices over the service life of the new assets (over 50 years).

2.2 Risk profile

There are varying consequences for each asset failure mode across different types of assets. CitiPower broadly categorises consequences as "Minor", "Disruptive" or "Catastrophic", and assigns an associated PoF for each category.

Minor failures result in a higher level of defect rectification. CitiPower reports that substations containing assets with a low rate of minor failures cost $4,000 per annum in routine maintenance, whereas those housing assets of deteriorating condition with high minor failure rates cost around $12,000 per annum.

The average cost when an asset failure occurs at ZS BK or ZS F is shown in Table 2. The table includes Consequence of Failure (CoF) applied in the economic analysis for the different options. It captures the quantifiable consequences for credible failure modes associated with the power and voltage transformers, circuit breakers, and sub-transmission supply. It does not capture a comprehensive build of all possible consequences for all assets and failure modes.

Table 2: Average cost when an asset failure occurs at ZS BK or F (Consequence of Failure – CoF)

Items	Disruptive	Catastrophic	Comments
Reliability	$0.2 m	$15.4 m	• Applies the Value of Customer Reliability (VCR) as per the Australian Energy Market Operator (AEMO), using the average for CitiPower's network. • Disruptive failures assume that power will be lost to a single feeder for a period for 2 hours (for feeder CBs only). ZS F does not have N-1 (due to failure of third transformer), so value of load at risk is included for a second transformer failure. • Catastrophic failure assumes entire substation load will be lost for three days until it can be restored using emergency diesel generators.
Safety	-	$0.1 m	• Assumes a fatality occurs for 1% of catastrophic failures, based on substation entry analysis.
Environment	$0.3 m	$1.2 m	• Assumes soil contamination rectification costs for bulk-oil assets.
Opex	$0.1 m	$19.5 m	• Assumes diesel generator running costs. • Assumes diesel generators required for a period of four weeks for a catastrophic transformer failure and a period for ten weeks for a catastrophic switchboard failure.
Capex	$2.1 m	$3.9 m	• Costs of unplanned asset replacement applies regular asset unit rates, as well emergency substation construction and fire damage costs.
TOTAL	**$2.6 m**	**$40 m**	

CitiPower has developed Condition Based Risk Management (CBRM) modelling for its transformer (TX) and circuit-breaker switchboard (SB) populations. Figure 5 shows the health distribution for these asset populations, and notes the TXs and SBs health index for the assets at ZS BK and F.

Figure 5: Health profiles for transformers (TX) and circuit-breaker switchboard (SB) populations

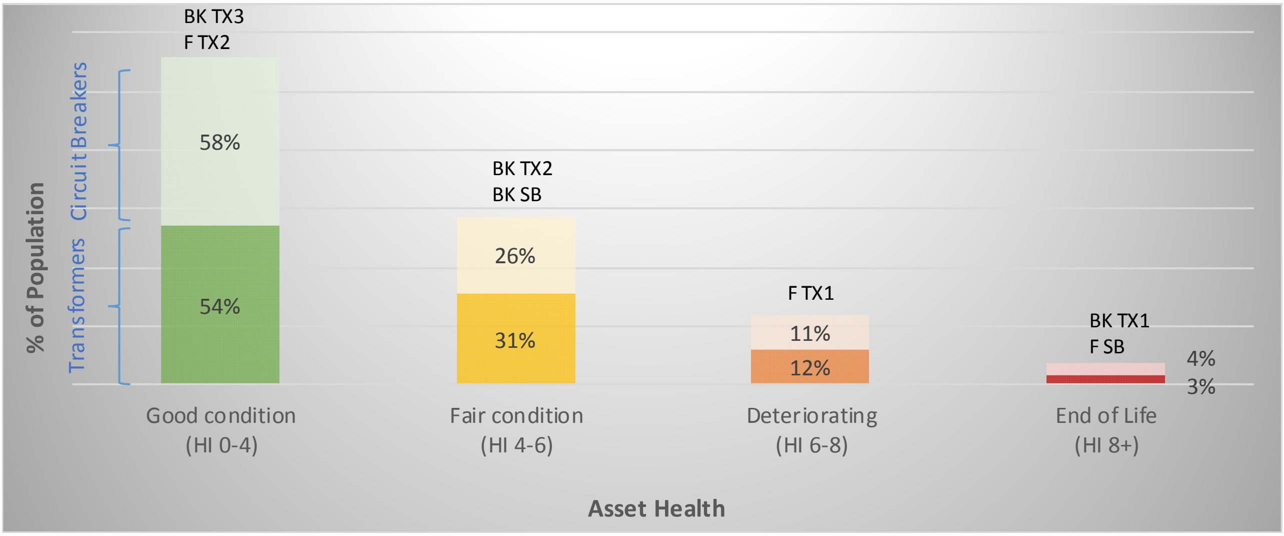


Figure 5 shows that Transformer No.1 at ZS BK (BK TX1) and the switchboard at ZS F (F SB) are approaching end of serviceable life, and that Transformer No.1 at ZS F (F TX1) is in deteriorating condition. These are the assets of immediate concern that require intervening action in the near term. The issues relating to construction constraints and good electricity industry practice (discussed in Sections refer to Sections 1.5, 1.6, 1.7 and 2.1, and unpacked in further detail throughout Sections 3 and 4) give rise to an options evaluation for the Brunswick area that is broader than piecemeal replacement of these assets.

The aggregate PoFs for ZS BK and F are provided in Table 3. It shows that, based on CitiPower's network data, over the next 12 months:

- There is a 12.4% likelihood of incurring a $3.6 m cost based on the average consequence of a disruptive failure; and
- There is a 0.6% likelihood of incurring a $40.5 m cost based on the average consequence of a catastrophic failure.

Table 3: Likelihood of incurring failure costs within the next 12 months

Zone substation	Probability of Disruptive Failure	Probability of Catastrophic Failure
Brunswick (BK)	7.7%	0.3%
Fitzroy (F)	4.7%	0.2%
TOTAL	**12.4%**	**0.6%**

3. Options

3.1 Option 1: Continued maintenance and monitoring

This option involves continuing the business-as-usual annual inspection and routine maintenance practices in ZS BK and ZS F.

The option has been analysed based on its associated direct costs (capex + opex) and risk costs (PoF × CoF); each of these are discussed in Table 4.

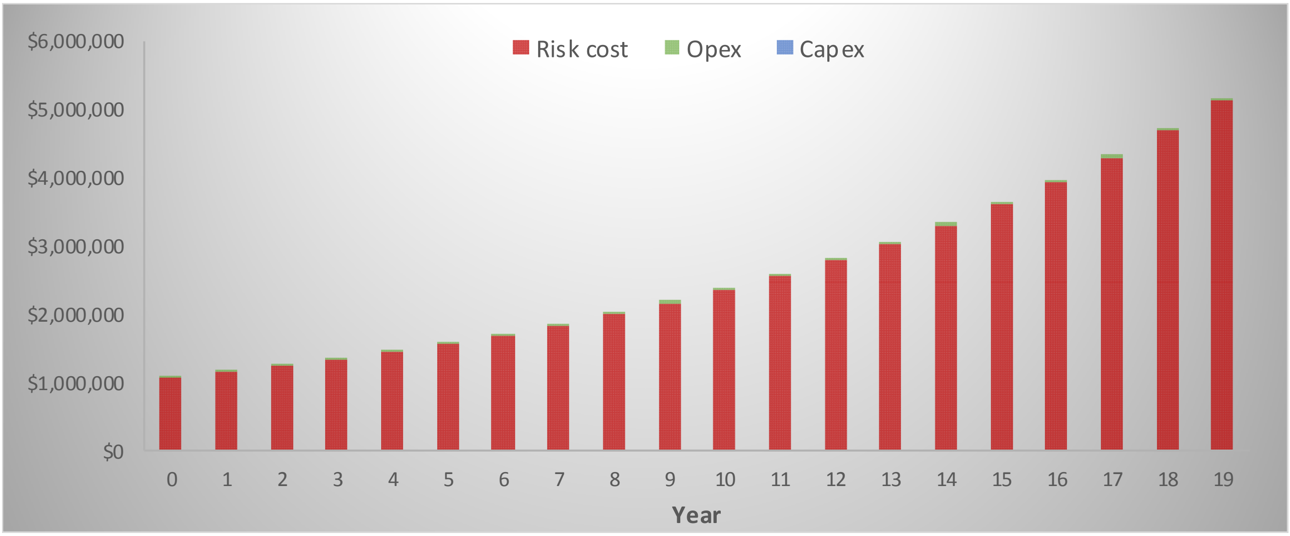
Table 4: Cost breakdown summary for Option 1

Cost category	Description
Capex	There is no planned capital expenditure (capex) associated with this option.
Opex	Due to the ageing assets and civil infrastructure, the cost for undertaking these activities at ZS BK and F is relatively high compared to CitiPower's other substations. The operational expenditure (opex) costs are around $24 k combined for ZS BK and ZS F each year, versus an average of around $4 k each year for other CitiPower substations. These opex costs continue increasing as the substation assets and civil infrastructure continue to deteriorate.
Risk costs	The increasing opex costs for defect maintenance are immaterial in relation to the costs that would be incurred should a disruptive or catastrophic asset failure occur (as discussed in Section 2.2). The total risk cost is calculated by applying the individual PoFs to the individual CoFs and summating the total. Presently, the annual risk cost carried by CitiPower by continuing the business-as-usual annual inspection and routine maintenance practices in ZS BK and ZS F is $1.07 m. These risk costs continue increasing as the substation assets and civil infrastructure continue to deteriorate (and the associated PoFs continue increasing).

Figure 6 shows the real cash flows for the option over the next 20 years. It illustrates the impact of the increasing risk profile for the option. As discussed in Section 2.2, the risk cost considers quantifiable consequences for credible failure modes and does not capture a comprehensive build of all possible consequences for all assets and failure modes.

Notably, only the PoFs are escalated over time, and the CoFs are not escalated. The reliability and opex items make up the greatest contribution to consequence of failure costs. The CoFs have not been escalated as this would require a range of potentially speculative economic analyses. However, it is noted that the impact of these categories would be expected to increase with demand profiles and increases in the cost of diesel, neither of which not factored into the analysis. As such, the assessment of risk costs is considered conservative.

Figure 6: Real cost cash flows for Option 1



3.2 Option 2: Non-network solutions

This option involves solutions that do not require investment in network assets to meet consumer demand for electrical power throughout the Brunswick area going forwards.[4]

The non-network solution considered includes retiring ZS BK and ZS F, and supplying their remaining loads using a portfolio of different technologies. The option has considered:

- **Operational initiatives** (i.e. transfer of demand to alternate network assets): We have assumed that the network can be reconfigured such that 20% of the load can be transferred to adjacent feeders supplied from neighbouring Zone Substations.
- **Demand management** (i.e. measures to reduce demand and consumption): We have assumed that demand management initiatives can be implemented such that peak demand can be reduced by 10%.
- **Embedded generation and storage** (i.e. alternate means of electricity supply to using network assets): We have assumed that embedded generation and storage will cater for the remaining 70% of demand.

[4] We note that CitiPower will be required to seek proposals from the market in relation to non-network solutions as part of the RIT-D process. Notwithstanding, the costs for the provision of non-network solution in full have been estimated for option analysis in this area plan. This should allow CitiPower to appreciate the scope of non-network solution required and the associated costs.

The option has been analysed based on its associated direct costs (capex + opex) and risk costs (PoF × CoF); each of these are discussed in Table 5. Note the cost estimates do not include any costs associated with network reconfiguration or demand management initiatives.

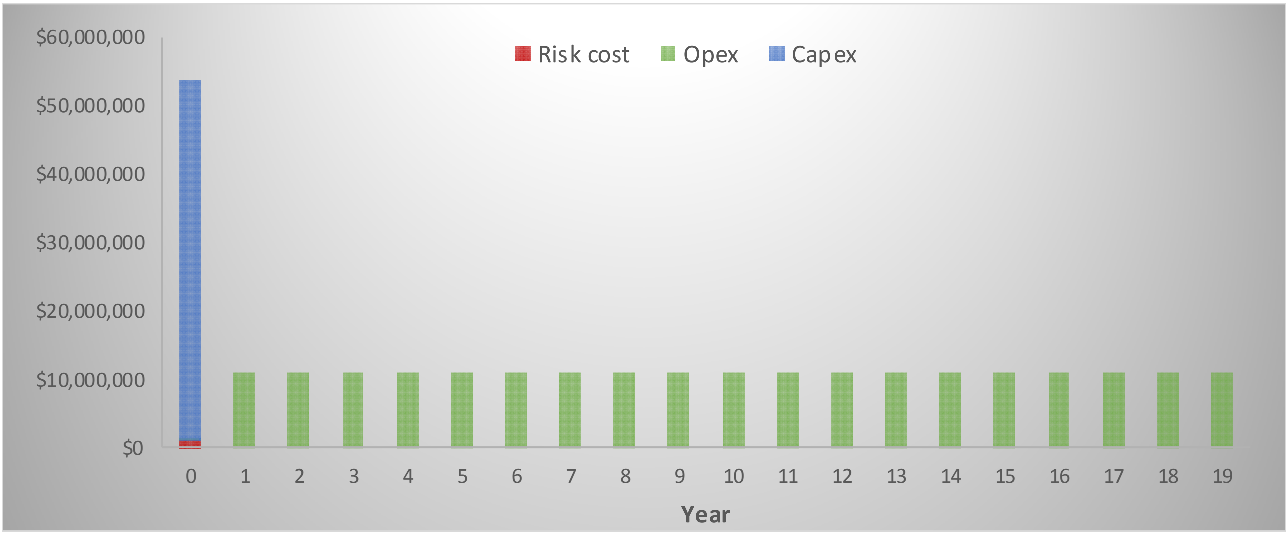
Table 5: Cost breakdown summary for Option 2

Cost category	Description
Capex	The solution includes a combination of local diesel generation complimented with local Solar Photovoltaic (SPV) generation and battery storage. The capex cost estimate includes the cost of diesel generators, solar panels, batteries and inverters. No other related infrastructure is included. The total cost of installing this infrastructure is estimated at $53 m (based on a unit price build of $2.5 m per MVA and a requirement for 10.5 MVA of remaining maximum demand each for both ZS BK and ZS F). The capex assumes that the existing substation sites would house the equipment and hence does not include any costs to decommission the existing substations and remediate the sites. As a price check, large scale solar projects supported by the Australian Renewable Energy Agency (ARENA) show total project costs of around $45 m for a 20 MW solar farm[5]. Similar scale developments within Melbourne's inner suburbs would be expected to incur higher costs.
Opex	Operational costs have been estimated for running the diesel generation at $10.9 m per annum. This allows for diesel generators supplying 35% of the total energy and running for 12 hours each day at $1.5 per litre of diesel. As per Option 1, increasing demand profiles have not been factored into the analysis.
Risk costs	Risk costs have not been estimated for the non-network solution. The risk cost for Option 1 ($1.07 m) applies in year zero only (until the non-network solution can be implemented). No value for risk is captured once the non-network solution is implemented.

Figure 7 shows the real cash flows for the option over the next 20 years.

[5] https://arena.gov.au/funding/programs/advancing-renewables-program/large-scale-solar-photovoltaics-competitive-round/

Figure 7: Real cost cash flows for Option 2



3.3 Option 3: Life extension of existing assets

This option involves undertaking refurbishment projects to extend the life of ZS BK and ZS F. This would target high risk assets and seek to reduce the probability or consequence of asset failures. For example, targeted renewals of asset items (e.g. transformer oil, tap changers or cooling systems) to reduce the associated risk and defer the retirement of the assets.

CitiPower has advised that it has already exhausted all possible options to extend the life of ZS BK and ZS F. Based on this advice the option is considered not credible and has not been investigated further. Note that piecemeal replacement options are considered in Option 4 (Section 3.4).

This option would perpetuate the issues relating to sub-standard construction and non-conformance with good electricity industry practice discussed in Section 2.1.

3.4 Option 4: Replacement of existing assets (in-situ)

This option involves in-situ rebuild of the ZS BK and F, including the replacement of primary plant, secondary systems, and the associated 22 kV sub-transmission feeders. The existing 6.6 kV distribution network would remain in service. This would require the temporary offload of ZS BK and F while the works are completed.

Note that this option was originally considered as a piecemeal replacement of end-of-life assets. However, upon developing this option it became apparent that piecemeal replacement would be unfeasible. This is because a significant proportion of assets have already reached end-of-life, including indoor switchboards. Consequently, offloading and significant construction works would be required to replace assets that have reached end-of-life. Retaining ageing assets on-site that are approaching end-of-life would mean that subsequent offloading and significant construction projects would be required again in the near future to replace these assets. Hence, a piecemeal replacement approach would result in substantially higher overall costs to manage the site and also attract a significantly higher risk profile.

Given both ZS BK and ZS F are situated in highly populated areas with restrictive space for construction activities, heavy vehicle traffic, and certain requirements and expectations from the local council and community (for e.g. working hours), the actual delivery of this option is challenging. This involves complex construction method, logistics planning, project organisation and switch-over scheduling. This difficulty has been captured in the capital cost estimate.

This option would perpetuate the issues relating to sub-standard construction and non-conformance with good electricity industry practice discussed in Section 2.1.

The option has been analysed based on its associated direct costs (capex + opex) and risk costs (PoF × CoF). The following considerations with respect to capex, opex and risk costs have been applied:

- **Capex:** The total capex for this option is estimated at $68 m. The scope of capital works required to rebuild ZS BK and F and temporarily offload ZS BK to ZS WB and ZS F SZ CW is provided in Table is provided in Table 6.

Table 6: Scope of capital works for Option 4

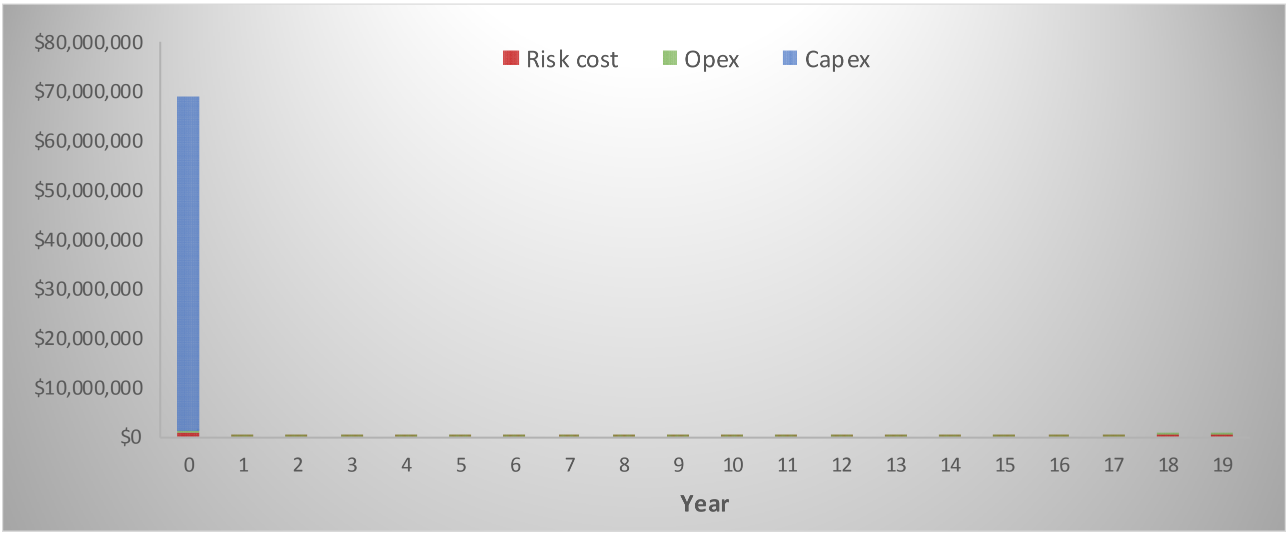
Categories	Asset items	Brunswick (BK)	Fitzroy (F)	West Brunswick (WB)	Collingwood (CW)	Comments
Sub-transmission	22 kV underground cable	8.4 km	8.1 km			Assuming three circuits feeding each zone substations.
Zone substation	22 kV underground cable terminations and indoor CB panels	3	3			Assuming new replacement will have protection at transformer primary side.
	22/6.6 kV 10 MVA transformer and associated civil works and secondary systems	2	2			Only the transformers at end of life will be replaced. The younger transformers (7 and 8 years old) will be retained).
	Aux/station transformer	1	1			
	6.6 kV indoor panels	15	19			Transformer protection, bus section and feeder protection.
	6.6 kV underground cable terminations	7	10			
	6.6/11 kV auto transformer	3	-			
	Civil works for new switch room and control room to house the indoor panels and secondary systems	1	1			
	Demountable switch room			1	1	
	Demountable control room			1	1	
	66 kV AIS complete switchbay			1		
	11 kV indoor panels			16	8	WB has 15×6.6 kV CBs. Including 15×6.6 kV CBs that BK has. Assuming the total in WB will be 23×11 kV CBs. =However with dual glanding

Categories	Asset items	Brunswick (BK)	Fitzroy (F)	West Brunswick (WB)	Collingwood (CW)	Comments
						expected to only need 16 CBs in WB. F presently has 19×6.6 kV CBs. Assuming when offloaded to CW it will be 13×11 kV CBs. However with dual glanding expected to only need 8 CBs in WB.
	11 kV underground cable termination			8	4	WB has 7×6.6 kV feeders. Including 7×6.6 kV feeders that BK has. Assuming the total in WB will be 8×11 kV feeders. F has 10×6.6 kV feeders. Assuming when offloaded to CW it will be 4×11 kV feeders
	11 kV capacitor bank			1		WB needs add an 11 kV cap bank
Distribution	6.6 kV underground cable, associated step-down distribution transformers and ring main units (RMUs)	-	-			GHD assumes that the 6.6 kV reticulation network continues to remain in place and no work is required
	11 kV underground cable			2.3	3.0	Assuming 3 circuits requiring work with an average 750 m length at WB. Assuming 500 m length required in each of the 6 feeders to pick up all F loads at 11 kV.
	11/0.4 kV distribution transformer, padmount/kiosk			16	40	16 existing non dual ratio transformers in BK operating at 6.6 kV. 56 distribution transformers in total on F. Assuming 29% are dual wound as per other subs average.

- **Opex:** This option would decrease CitiPower's annual costs for routine inspection and maintenance from $24 k to $8 k combined for ZS BK and ZS F each year. This increases as the assets deteriorate over their projected 50 year lifespan.
- **Risk costs:** Renewing the assets in ZS BK and ZS F results in a substantial reduction in risk costs. This reduces from $1.07 m in year zero (prior to implementation) to $117 k in year one. This difference rapidly increases compared to Option 1 (continued maintenance and monitoring) where the PoFs for deteriorating assets approaching end of life increase exponentially; whereas the PoFs for the renewed assets under this option increase gradually over their 50 year service life.

Figure 8 shows the real cash flows for the option over the next 20 years.

Figure 8: Real cost cash flows for Option 4



3.5 Option 5: Retirement of existing assets

This section considers four separate options for retiring existing assets:

- Option 5a: Redevelop ZS C and offload ZS F and ZS BK to ZS C at 22/6.6 kV
- Option 5b: Redevelop ZS C and offload ZS F and ZS BK to ZS C at 66/11 kV
- Option 5c: Offload ZS F to ZS CW and ZS BK to ZS WB at 66/6.6 kV
- Option 5d: Offload ZS F to ZS CW and ZS BK to ZS WB at 66/11 kV

The overview of Brunswick area and its electricity distribution system is described in Section 1.5. Zone substations BK, F and C are supplied by AusNet's Brunswick Terminal Substation (BTS) at 22 kV. The 22 kV underground cables from BTS are among the oldest CitiPower assets. Zone substations NC and WB form a 66 kV ring and are supplied by AusNet's West Melbourne Terminal Substation (WMTS) at 66 kV (the 66 kV assets are not approaching end-of-life).

ZS C has reached end of life and is being retired and offloaded to ZS WB (currently undergoing RIT-D process). This means that the ZS C site is not being utilised.

In this evaluation, the NC zone substation is not considered in any retirement, replacement, offloading and consolidating options of other zone substations in Brunswick area because NC zone substation is geographically further away and is also separated by a river. Any work connecting to NC zone substation will involve river crossing and hence is likely to be uneconomical.

3.5.1 Option 5a: Redevelop ZS C and offload ZS F and ZS BK to ZS C at 22/6.6 kV

This option involves retiring BK and F zone substations from service and transferring their respective loads to redeveloped ZS C and retaining the same 22/6.6 kV transformation voltage levels.

This option enables redeveloped C zone substation to supply loads of ZS BK and F over an assumed 50 year service life. Consolidating and optimising the two sites to one will result in a reduced overall asset quantum; however, it also reduces network security i.e. in the event that a catastrophic failure occurs the combined loads of ZS BK and F will be lost.

This option would perpetuate the issues relating to good electricity industry practice discussed in Section 2.1.

The option has been analysed based on its associated direct costs (capex + opex) and risk costs (PoF × CoF). The following considerations with respect to capex, opex and risk costs have been applied:

- **Capex:** The total capex for this option is estimated at $37 m. This will include decommissioning assets at BK and F zone station and redeveloping C zone substation site to house new modern equivalent assets to supply BK and F zone substations loads. This also involves extending the 6.6 kV distribution network from C zone substation to connect to existing feeders supplying BK and F zone substation loads. The scope of work in this option includes the following assets as shown in Table 7.

Table 7: Scope of capital works for Option 5a

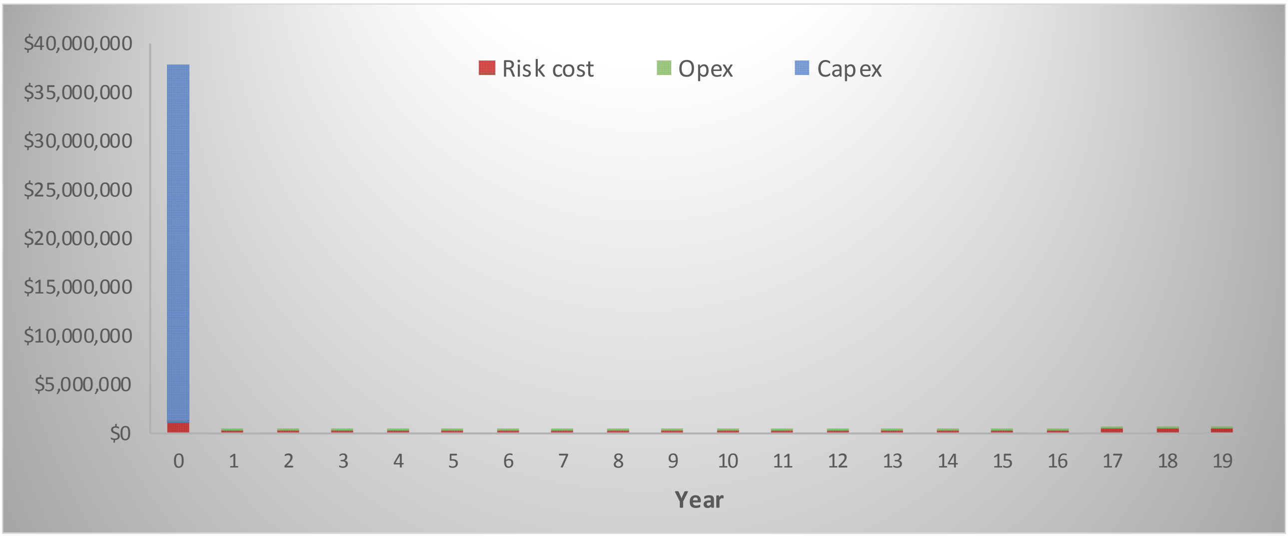
Categories	Asset items	Brunswick (BK)	Fitzroy (F)	Brunswick (C)	Comments
Sub-transmission	22 kV underground cable			3.9 km	Assuming two circuits supplying two new transformers in C.
Zone substation	Zone substation decommissioning and site remediation (civil works)	1	1		
	Redevelopment of C site (after offloading C load to WB). In-situ extension/rework of existing switch room and control rooms in C to accommodate new indoor panels and secondary systems (civil works)			1	Offloading of C load to WB is as per the preferred option described in the RIT-D documents for C zone substation.
	22 kV underground cable terminations and indoor CB panels			2	Assuming offloading of BK and F to C will consolidate and optimise primary plants required to supply BK and F loads. Assuming new extension will have protection at transformer primary side.
	22/6.6 kV 30 MVA transformer and associated civil works and secondary systems			2	Assuming 3×10 MVA in BK and 3×10 MVA in F are consolidated to 2×30 MVA in C.
	Aux/station transformer			1	
	6.6 kV indoor panels			34	Transformer protection, bus section and feeder protection. Optimise the total from BK and F
	6.6 kV underground cable terminations			17	Optimise the total from BK and F
Distribution	6.6 kV underground cable			6.8 km	New cables required to connect to existing 6.6 kV feeders.
	6.6/0.4 kV distribution transformers			50	
	6.6 kV RMUs			0	No new RMUs needed.

- **Opex:** This option would decrease CitiPower's annual costs for routine inspection and maintenance from $24 k to $4 k combined for ZS BK and ZS F each year. This increases as the assets deteriorate over their projected 50 year lifespan.
- **Risk costs:** Renewing the ZS BK and ZS F assets results in a substantial reduction in risk costs. However, there is an increased network security risk in the event of a catastrophic failure (with two

substation sites being amalgamated into a single site), where the combined loads of ZS BK and F will be lost. This has a net effect of reducing risk costs from $1.07 m in year zero (prior to implementation) to $175 k in year one. This difference rapidly increases compared to Option 1 (continued maintenance and monitoring) where the PoFs for deteriorating assets approaching end of life increase exponentially; whereas the PoFs for the renewed assets under this option increase gradually over their 50 year service life.

Figure 9 shows the real cash flows for the option over the next 20 years.

Figure 9: Real cost cash flows for Option 5a



3.5.2 Option 5b: Redevelop ZS C and offload ZS F and ZS BK to ZS C at 66/11 kV

This option involves retiring BK and F zone substations from service and transferring their respective loads to redeveloped C zone substation using the 66/11 kV transformation voltage levels. This option also involves upgrading the reticulation supplying the loads previously fed from C zone substation (and now offloaded to WB zone substation) at 6.6 kV to 11 kV because the previous RIT-D did not allow for such upgrade. This will make all the reticulation at compatible 11 kV across the entire Brunswick area.

As with Option 5a (refer to Section 3.5.1), the option allows the sites to be consolidated and optimised, but results in a trade-off where network security is reduced.

However, this option offers additional benefits in relation to Option 5a. Whereby additional optimisation is achieved by reducing the quantity of assets required to supply at 11 kV than is required for 6.6 kV distribution. It also overcomes all of the issues relating to the existing assets' non-conformance with good electricity industry practice discussed in Section 2.1.

The option has been analysed based on its associated direct costs (capex + opex) and risk costs (PoF × CoF). The following considerations with respect to capex, opex and risk costs have been applied:

- **Capex:** The total capex for this option is estimated at $30 m. This will include decommissioning assets at BK and F zone substations and redeveloping C zone substation site to house new modern equivalent assets to supply BK and F zone substations loads. This will involve upgrading the sub-transmission feeders to 66 kV incoming to C zone substation. This will also involve upgrading and extending the 11 kV distribution network from C zone substation to connect to existing feeders supplying BK and F zone substation loads. The scope of work in this option includes the following assets as shown in Table 8.

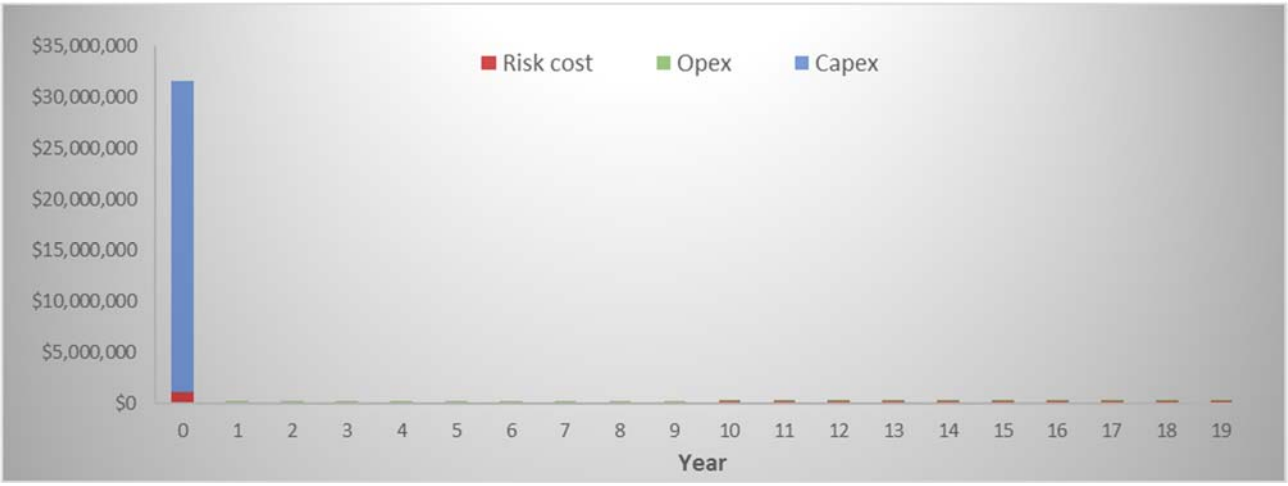
Table 8: Scope of capital works for Option 5b

Categories	Asset items	Brunswick (BK)	Fitzroy (F)	Carlton (C)	Comments
Sub-transmission	66 kV incoming feeder			0.2 km	66 kV supplied from WMTS directly and cut-in from 66 kV line from WMTS to NC (i.e. loop-in-loop-out at C). Two incoming feeders for redundancy/supply security.
Zone substation	Zone substation decommissioning and site remediation (civil works)	1	1		
	Redevelopment of site (after offloading C load to WB). In-situ extension/rework of existing switch room and control rooms to accommodate new indoor panels and secondary systems (civil works)			1	Offloading of C load to WB is as per the preferred option described in the RIT-D documents for C zone substation.
	66 kV feeder terminations and outdoor AIS (or indoor GIS) switchbay			2	Assuming offloading of BK and F to C will consolidate and optimise primary plants required to supply BK and F loads. Assuming new extension will have protection at transformer primary side.
	66/11 kV 30 MVA transformer and associated civil works and secondary systems			2	Assuming 3×10 MVA in BK and 3×10 MVA in F are consolidated to 2×30 MVA in C.
	Aux/station transformer			1	
	11 kV indoor panels			24	There are a total of 34 × 6.6 kV CB panels presently in F and BK. Assuming it will be replaced by 24 × 11 kV CB panels for similar capacity. Transformer protection, bus section and feeder protection.
	6.6 kV underground cable terminations			12	There are a total of 17 × 6.6 kV distribution feeders presently originating from F and BK. Assuming it will be replaced by 12 × 11 kV distribution feeders for similar capacity.
Distribution	11 kV underground cable			5.3km	Assume 100m required to connect to existing feeders. Assume all existing 6.6 kV network is insulated to 11 kV.
	11/0.4 kV distribution transformer padmount /kiosk			56	Assume the 'unknown' distribution transformers being supplied from BK and F are single ratio 6.6 kV.
	11 kV RMUs			-	Assuming all existing RMUs are 11 kV.
	Upgrading the reticulation supplying the load being fed from C and WB zone substations to 11 kV			1 lot (C and WB)	This cost is not included in the previous RIT-D. Allowing this capex in this option will result in the risk reduction.

- **Opex:** This option would decrease CitiPower's annual costs for routine inspection and maintenance from $24 k to $4 k combined for ZS BK and ZS F each year. This increases as the assets deteriorate over their projected 50 year lifespan.
- **Risk costs:** As with Option 5a, renewing the ZS BK and ZS F assets results in a substantial reduction in asset failure risks but an increase network security risk in the event of a catastrophic failure. However, the reliability risks are reduced by the upgrade to 11 kV, which will allow network reconfigurations to restore supply to faulted feeders. This has a net effect of reducing risk costs from $1.07 m in year zero (prior to implementation) to $126 k in year one. This difference rapidly increases compared to Option 1 (continued maintenance and monitoring) where the PoFs for deteriorating assets approaching end of life increase exponentially; whereas the PoFs for the renewed assets under this option increase gradually over their 50 year service life.

Figure 10 shows the real cash flows for the option over the next 20 years.

Figure 10: Real cost cash flows for Option 5b



3.5.3 Option 5c: Offload ZS F to ZS CW and ZS BK to ZS WB at 66/6.6 kV

This option involves retiring BK and F zone substations from service and transferring their loads to WB and CW zone substations respectively at 66/6.6 kV transformation voltage levels.

This option enables ZS WB and CW to supply loads of ZS BK and F over an assumed 50 year service life.

Consolidating the two sites and offloading them to two existing sites, together with consolidation and optimisation of network replacement assets, will result in rationalised Regulatory Asset Base (RAB). However, it also reduces network security i.e. in the event that a catastrophic failure occurs the combined loads will be lost for ZS BK and WB, or ZS F and CW.

This option would perpetuate the issues relating to good electricity industry practice discussed in Section 2.1.

The option has been analysed based on its associated direct costs (capex + opex) and risk costs (PoF × CoF). The following considerations with respect to capex, opex and risk costs have been applied:

- **Capex:** The total capex for this option is estimated at $26 m. This will include decommissioning assets at BK and F zone substations and augmenting WB and CW zone substations sites to accommodate modern equivalent assets to supply BK and F zone substations loads respectively. This will involve extending the 6.6 kV distribution network from WB and CW zone substations to connect to existing feeders supplying BK and F zone substation loads, and if necessary installation of 11/6.6 kV auto transformers downstream of CW zone substation. The scope of work in this option includes the following assets as shown in Table 9.

Table 9: Scope of capital works for Option 5c

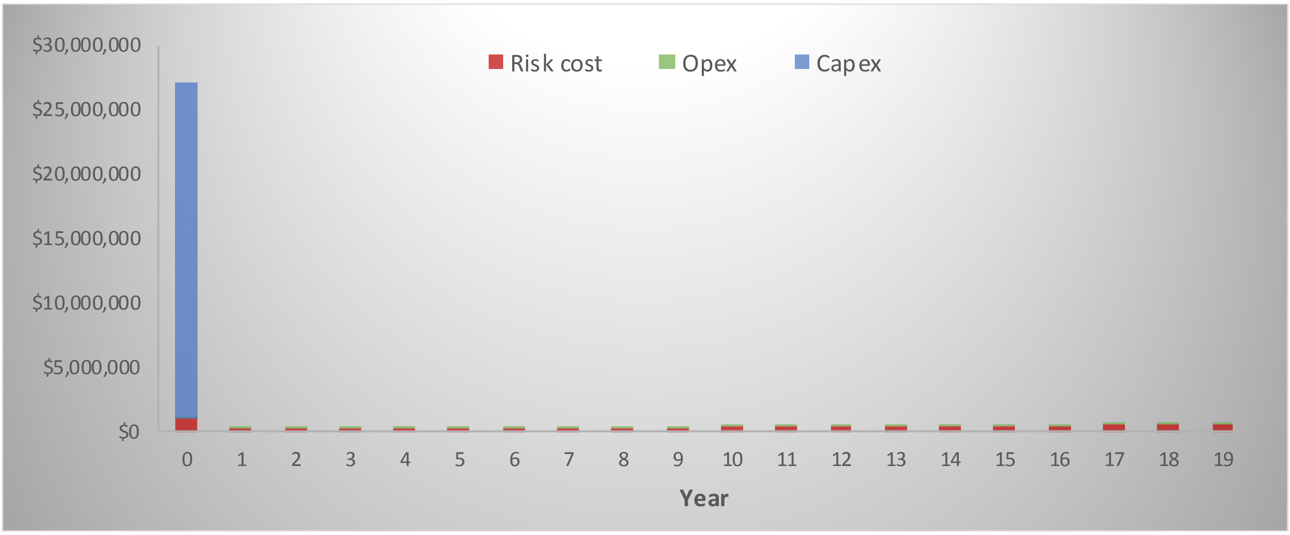
Categories	Asset items	BK	WB	F	CW	Comments
Sub-transmission	66 kV incoming feeder		-		-	New or additional 66 kV supplies are not required.
Zone substation	Zone substation decommissioning and site remediation (civil works)	1		1		
	In-situ extension of existing switch rooms and control rooms in to accommodate new indoor panels and secondary systems (civil works)		1		1	
	66 kV busbar extension 66 kV outdoor AIS (or indoor GIS) switchbay		-		-	Sub-transmission extension is included in the scope for another project (the transfer the existing ZS C to ZS WB). So is not required for this option. Not extending the bus in CW as there is no room for the 3rd transformer and also no need to run CW with N-1 contingency.
	66/6.6 kV 30MVA transformer and associated civil works and secondary systems		-			Sub-transmission extension is included in the scope for another project (the transfer the existing ZS C to ZS WB). So is not required for this option.
	66/11 kV 27MVA transformer and associated civil works and secondary systems				-	Max demand at CW is about 28 MVA. F max demand is about 15 MVA. Assuming they do not have demand diversity, the total will be about 43 MVA. There is no room for the 3rd transformer and also no need to run CW with N-1 contingency.
	6.6 kV indoor panels		15			Transformer protection, bus section and feeder protection.
	11 kV indoor panels				13	F presently has 19 × 6.6 kV CB panels. Assuming when offloaded to CW it will be 13 × 11 kV CB panels. Transformer protection, bus section and feeder protection.
	6.6 kV underground cable terminations		7			
	11 kV underground cable terminations				6	F presently has 10 × 6.6 kV feeders. Assuming when offloaded to CW it will be 6 × 11 kV feeders
	11/6.6 kV auto transformer distribution feeder		3		6	Assuming 3 new auto transformers required at WB to step up to 11 kV to supply 3×11 kV feeders from BK Assuming auto transformer is required for one feeder only as F will need to be converted to 11 kV
	6.6 kV cap bank				2	Assuming CW needs to change its existing 11 kV cap banks to 6.6 kV cap banks
Distribution	6.6 kV underground cable		3.8km			Assuming 5 circuits requiring work with an average 750m length at WB.
	11 kV underground cable				3.0km	Assuming 500m length required in each of the 6 feeders to pick up all F loads at 11 kV.
	6.6/0.4 kV distribution transformer padmount /kiosk		10		40	56 distribution transformers in total on F. Assuming 29% are dual wound as per other subs average.
	6.6 kV RMUs		0		0	No new RMUs needed.

- **Opex:** This option will decrease CitiPower's annual costs for routine inspection and maintenance from $24 k to $8 k combined for ZS BK and ZS F each year. This increases as the assets deteriorate over their projected 50 year lifespan.

- **Risk costs:** As with Options 5a and 5b, renewing the ZS BK and ZS F assets results in a substantial reduction in asset failure risks but an increase in network security risk in the event of a catastrophic failure. In this Option, the network security risks are greater than 5a and 5b because the loads of ZSs CW and WB are also placed at risk. This has a net effect of reducing risk costs from $1.07 m in year zero (prior to implementation) to $224 k in year one. This difference rapidly increases compared to Option 1 (continued maintenance and monitoring) where the PoFs for deteriorating assets approaching end of life increase exponentially; whereas the PoFs for the renewed assets under this option increase gradually over their 50 year service life.

Figure 11 shows the real cash flows for the option over the next 20 years.

Figure 11: Real cost cash flows for Option 5c



3.5.4 Option 5d: Offload ZS F to ZS CW and ZS BK to ZS WB at 66/11 kV

This option involves retiring BK and F zone substations from service and transferring their loads to WB and CW zone substation respectively at 66/11 kV transformation voltage levels. This option also involves upgrading the reticulation supplying the loads previously fed from C zone substation (and now offloaded to WB zone substation) at 6.6 kV to 11 kV because the previous RIT-D did not allow for such upgrade. This will make all the reticulation at compatible 11 kV across the entire Brunswick area.

As with Option 5c (refer to Section 3.5.3), the option allows the sites to be consolidated and optimised, but results in a trade-off where network security is reduced.

However, this option offers additional benefits in relation to Option 5c. Whereby additional optimisation is achieved by reducing the quantity of assets required to supply at 11 kV than is required for 6.6 kV distribution. It also overcomes all of the issues relating to good electricity industry practice discussed in Section 2.1.

The option has been analysed based on its associated direct costs (capex + opex) and risk costs (PoF × CoF). The following considerations with respect to capex, opex and risk costs have been applied:

- **Capex:** The total capex for this option is estimated at $26 m. This will include decommissioning assets at BK and F zone substations and augmenting WB and CW zone substations sites to accommodate modern equivalent assets to supply BK and F zone substation loads respectively. This will involve extending the 11 kV distribution network from WB and CW zone substations to connect to existing feeders supplying BK and F zone substation loads. This will also involve installing new distribution transformers being supplied at 11 kV downstream of WB and CW zone substations. The scope of work in this option includes the following assets as shown in Table 10.

Table 10: Scope of capital works for Option 5d

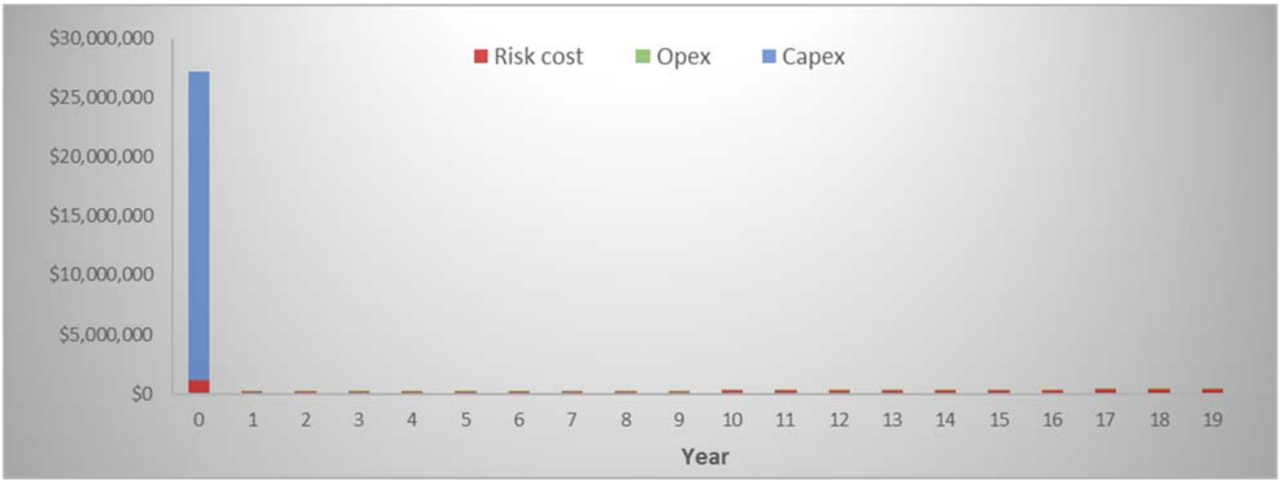
Categories	Asset items	BK	WB	F	CW	Comments
Sub-transmission	66 kV incoming feeder		-		-	New or additional 66 kV supplies are not required.
Zone substation	Zone substation decommissioning and site remediation (civil works)	1		1		
	In-situ extension of existing switch rooms and control rooms in to accommodate new indoor panels and secondary systems (civil works)		1		1	
	66 kV busbar extension 66 kV outdoor AIS (or indoor GIS) switchbay		-		-	Sub-transmission extension is included in the scope for another project (the transfer the existing ZS C to ZS WB). So is not required for this option. Not extending the bus in CW as there is no room for the 3rd transformer and also no need to run CW with N-1 contingency.
	66/11 kV 30MVA transformer and associated civil works and secondary systems		-			Subtransmission extension is included in the scope for another project (the transfer the existing ZS C to ZS WB). So is not required for this option.
	66/11 kV 27MVA transformer and associated civil works and secondary systems				-	Max demand at CW is about 28 MVA. F max demand is about 15 MVA. Assuming they do not have demand diversity, the total will be about 43 MVA. There is no room for the 3rd transformer and also no need to run CW with N-1 contingency.
	11 kV indoor panels		16		8	WB presently has 15×6.6 kV CBs. Including 15×6.6 kV CBs that BK presently has. Assuming the total in WB will be 23×11 kV CBs. However with dual glanding expected to only need 16 CBs in WB. F presently has 14×6.6 kV CBs. Assuming when offloaded to CW it will be 13×11 kV CBs. However with dual glanding expected to only need 8 CBs in CW.
	11 kV underground cable terminations		8		4	WB presently has 7×6.6 kV feeders. Including 7×6.6 kV feeders that BK presently has. Assuming the total in WB will be 8×11 kV feeders. F presently has 10×6.6 kV feeders. Assuming when offloaded to CW it will be 4×11 kV feeders
	11 kV cap bank		1			WB needs to change its existing 6.6 kV cap bank to 11 kV cap bank
Distribution	11 kV underground cable		2.3k m		3.0k m	Assuming 3 circuits requiring work with an average 750 m length at WB. Assuming 500 m length required in each of the 6 feeders to pick up all F loads at 11 kV.
	11/0.4 kV distribution transformer padmount /kiosk		16		40	16 existing non dual ratio transformers in BK operating at 6.6 kV.

Categories	Asset items	BK	WB	F	CW	Comments
						56 distribution transformers in total on F. Assuming 29% are dual wound as per other subs average.
	11 kV RMUs		0		0	Assuming all existing RMUs are 11 kV.
	Upgrading the reticulation supplying the load being fed from C and WB zone substations to 11 kV		1 lot (C and WB)			This cost is not included in the previous RIT-D. Allowing this capex in this option will result in the risk reduction.

- **Opex:** This option would decrease CitiPower's annual costs for routine inspection and maintenance from $24 k to $8 k combined for ZS BK and ZS F each year. This increases as the assets deteriorate over their projected 50 year lifespan.
- **Risk costs:** As with Option 5c, renewing the ZS BK and ZS F assets results in a substantial reduction in asset failure risks but an increase network security risk in the event of a catastrophic failure. However, the reliability risks are reduced by the upgrade to 11 kV, which will allow network reconfigurations to restore supply to faulted feeders. This has a net effect of reducing risk costs from $1.07 m in year zero (prior to implementation) to $151 k in year one. This difference rapidly increases compared to Option 1 (continued maintenance and monitoring) where the PoFs for deteriorating assets approaching end of life increase exponentially; whereas the PoFs for the renewed assets under this option increase gradually over their 50 year service life.

Figure 12 shows the real cash flows for the option over the next 20 years.

Figure 12: Real cost cash flows for Option 5d



4. Preferred option

4.1 Options evaluation

4.1.1 Annualised cost comparison

Table 11 provides a comparison of capex and annualised cost for each option; where the annualised cost is the sum of Direct Costs (capex + opex) and Risk Costs over the service life discounted to Net Present Values (NPV) using CitiPower's Real WACC discount rate.

Table 11: Annualised costs comparison and ranking of all considered options

Options	Capex	Annualised cost	Rank
Option 1: Continued maintenance and monitoring	$0	$13.8 m	7
Option 2: Non-network solutions	$53 m	$13.7 m	6
Option 3: Life extension of existing assets	N/A	N/A	N/A
Option 4: Replacement of existing assets (in-situ)	$68 m	$3.2 m	5
Option 5a: Redevelop ZS C and offload ZS F and ZS BK to ZS C at 22/6.6 kV	$37 m	$2.1 m	4
Option 5b: Redevelop ZS C and offload ZS F and ZS BK to ZS C at 66/11 kV	$30 m	$1.7 m	2
Option 5c: Offload ZS F to ZS CW and ZS BK to ZS WB at 66/6.6 kV	$26 m	$1.8 m	3
Option 5d: Offload ZS F to ZS CW and ZS BK to ZS WB at 66/11 kV	$26 m	$1.6 m	1

** Note that Option 3 (Life extension of existing assets) was considered not credible based on advice from CitiPower and supported by the analysis of historical trend of defective events.*

4.1.2 Comparative advantages and disadvantages

Figure 13 provides a comparison of the annualised costs for the options considered. It illustrates the comparative breakdown of capex, opex and risk costs comprising the annualised cost for each option.

Figure 13: Annualised costs of all options ($m)

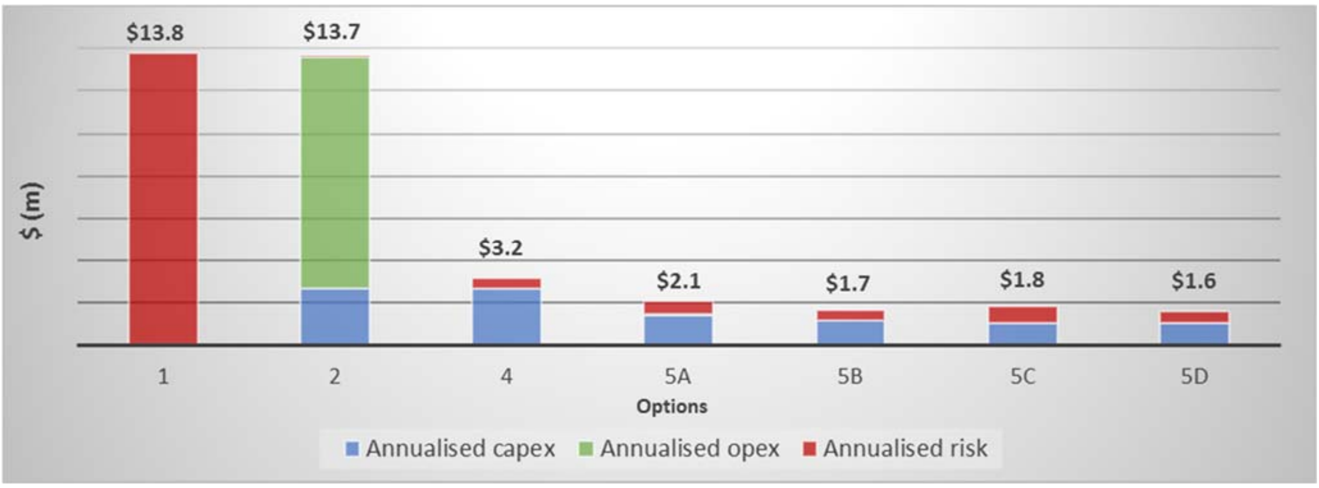


Table 12 provides a qualitative discussion of the comparative advantages and disadvantages of each option.

Table 12: Qualitative discussion of comparative advantages and disadvantages

Options	Advantages	Disadvantages
Option 1: Continued maintenance and monitoring	• No capital investment required.	• Option has an exponentially increasing risk profile that will ultimately result in disruptive and catastrophic failures. • It does not overcome issues relating to non-conformance with good electricity industry practice.
Option 2: Non-network solutions	• Does not require network investment.	• Very high ongoing operational investment is required • This is the highest cost option • Risk costs have not been evaluated
Option 3: Life extension of existing assets	• N/A – CitiPower advises it has already exhausted all possible options to extend the life of ZS BK and ZS F. Historical trend of defective events indicates increasing costs to repair these defects in both the sites. Option not credible and not evaluated.	
Option 4: Replacement of existing assets (in-situ)	• None identified.	• Option attracts a higher capital cost than other network solutions due to on-site construction difficulties. • It does not overcome issues relating to good electricity industry practice.
Option 5a: Redevelop ZS C and offload ZS F and ZS BK to ZS C at 22/6.6 kV	• Reduced risk profile compared to Option 1. • Redevelopment and future use/sale of two offloaded sites (ZS BK and ZS F).	• Option reduces network security. • It does not overcome issues relating to non-conformance with good electricity industry practice.
Option 5b: Redevelop ZS C and offload ZS F and ZS BK to ZS C at 66/11 kV	• Reduced risk profile compared to Option 1. • Redevelopment and future use/sale of two offloaded sites (ZS BK and ZS F). • Option has a lower capex than Option 5a due to less assets required at 11 kV compared to 6.6 kV. • The reduction in network security is partially mitigated compared to Option 5a due to the ability to reconfigure the network to restore power at 11 kV. • Option overcomes issues in relation to good electricity industry practice.	• Option reduces network security.
Option 5c: Offload ZS F to ZS CW and ZS BK to ZS WB at 66/6.6 kV	• This is the lowest capex solution. • Reduced risk profile compared to Option 1. • Redevelopment and future use/sale of two offloaded sites (ZS BK and ZS F), plus ZS C site remains unutilised.	• Option reduces network security. • It does not overcome issues relating to non-conformance with good electricity industry practice.
Option 5d: Offload ZS F to ZS CW and ZS BK to ZS WB at 66/11 kV	• This is the lowest total cost solution. • Option reduces network security, but this risk is reduced at 11 kV due to the ability to reconfigure the network to restore power. • Reduced risk profile compared to Option 1. • Redevelopment and future use/sale of two offloaded sites (ZS BK and ZS F), plus ZS C site remains unutilised. • Option overcomes issues in relation to non-conformance with good electricity industry practice associated with other options.	• Option reduces network security.

4.1.3 Preferred option

The evaluation demonstrates that Option 5d (Offload ZS F to ZS CW and ZS BK to ZS WB at 66/11 kV) is the most prudent and efficient solution to manage the issues highlighted in Section 2. This assessment is based on the evaluation of Direct Cost (capex + opex) and Risk Cost, and comparative advantages and disadvantages.

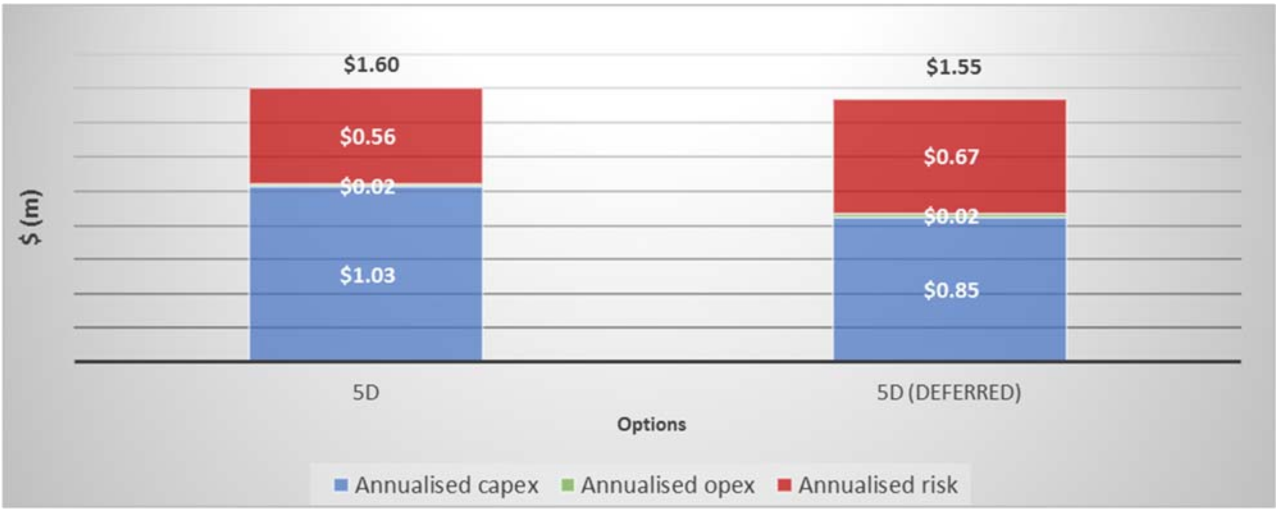
4.2 Preferred option implementation plan

Figure 14 compares the annualised costs for the preferred option if implemented immediately and if deferred to an optimal implementation timing. The optimal solution is to defer the implementation of the preferred option to 2023.

Deferring the investment discounts the annualised capex spend for Option 5d from $1.03 m to $0.85 m. This requires continuing with Option 1 (continued maintenance and monitoring) and accumulating associated risk through to 2022.

The total annualised cost for implementing the optimal solution in 2023 is $1.55 m, versus $1.60 m for implementing the option now.

Figure 14: Annualised costs ($m) for option 5D (immediate and deferred to 2023)



4.3 Preferred option sensitivity analysis

Sensitivity analysis was conducted on key assumptions that could affect the final cost, optimal timing and preferred option. This analysis consisted of looking at changes of ±10% and ±20% in the direct and risk costs individually and in combination (16 sensitivities in total). None of the sensitivity scenarios presented another option as potentially preferable.

Figure 15 illustrates the spread of the optimal timing of Option 5d under the various sensitivity scenarios and the base scenario. The optimal year of implementation of 2023 is the most common result. The average optimal year of implementation is 2023.

The sensitivity analyses skew towards an earlier implementation, which suggests expediting the implementation may be prudent; however, they do not present a strong case for doing so.

Figure 15: Optimal timing of Option 5d under various sensitivity scenarios and base scenario

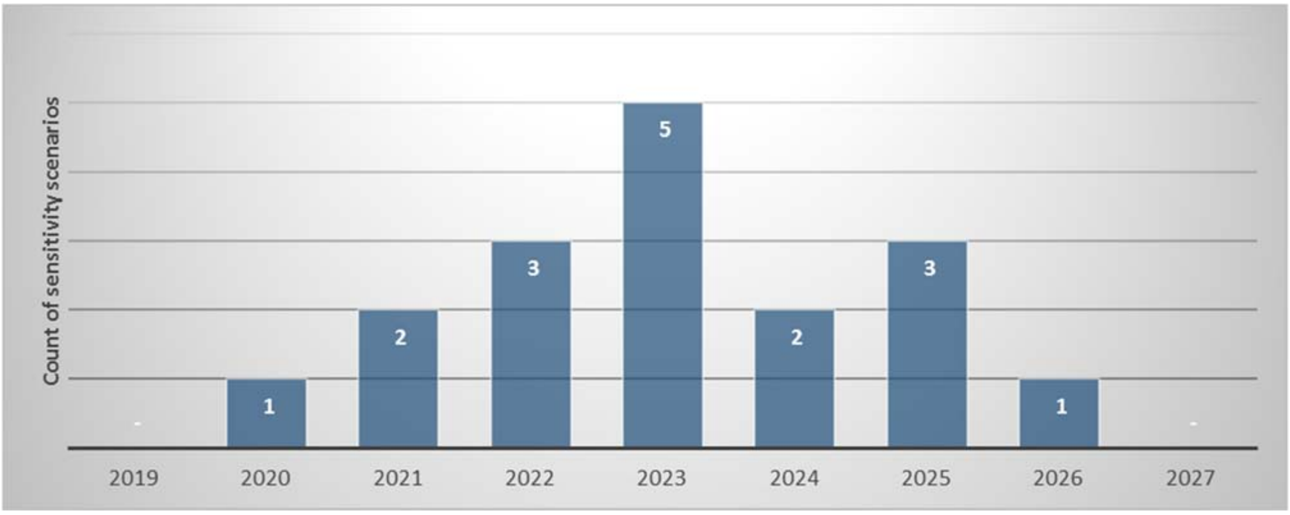


Table 13 provides a breakdown of optimal timing for each sensitivity scenario considered (as shown in Figure 15). The sensitivity analyses independently toggled direct costs and risk costs up and down, and then toggled both together in the same direction and also in opposite directions.

Table 13: Optimal year of implementation for the preferred option

Scenarios variables		Optimal year of implementation
Cost Category	Sensitivities	
Direct costs	+10%	2024
	+20%	2025
	-10%	2022
	-20%	2021
Risk costs	+10%	2022
	+20%	2022
	-10%	2024
	-20%	2025
Direct and risk costs (same direction)	+10%	2023
	+20%	2023
	-10%	2023
	-20%	2023
Direct and risk costs (opposite directions)	±10%	2025
	±20%	2026
	-+10%	2021
	-+20%	2020
BASE SCENARIO		2023
AVERAGE OF ALL SCENARIOS		**2023.1**

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