

CITIPOWER

DISTRIBUTION

ANNUAL

PLANNING

REPORT

Disclaimer

The purpose of this document is to provide information about actual and forecast constraints on CitiPower's distribution network and details of these constraints, where they are expected to arise within the forward planning period. This document is not intended to be used for other purposes, such as making decisions to invest in generation, transmission or distribution capacity.

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1 Overview

The Distribution Annual Planning Report (**DAPR**) provides an overview of the current and future changes that CitiPower proposes to undertake on its network. It covers information relating to 2021 as well as the forward planning period of 2022 to 2026.

CitiPower is a regulated Victorian electricity distribution business. It distributes electricity to around 345,000 homes and businesses in Melbourne's central business district (**CBD**) and inner suburbs. The network consists of 57,776 poles and over 4,173 kilometres of wires. Electricity is received via 108 sub transmission lines at 38 zone substations, where it is transformed from sub-transmission voltages to distribution voltages.

The report sets out the following information:

- forecasts, including capacity and load forecasts, at the zone substation, sub-transmission and primary distribution feeder level
- system limitations, which include limitations resulting from the forecast load exceeding the capacity following an outage of an asset, or retirements and de-ratings of assets
- projects that have been, or will be, assessed under the regulatory investment test
- other high level summary information to provide context to CitiPower's planning processes and activities.

The DAPR provides a high-level description of the balance that CitiPower will take into account between capacity, demand and replacement of its assets at each zone substation and sub-transmission line over the forecast period. This document should be read in conjunction with the System Limitation Report and the Forecast Load Sheet. Transmission-distribution connection assets are addressed in a separate report.¹

Data presented in this report may indicate an emerging major constraint, where more detailed analysis of risks and options for remedial action by CitiPower are required.

The DAPR also provides preliminary information on potential opportunities to prospective proponents of non-network solutions at zone substations, sub-transmission lines and primary distribution feeders where remedial action may be required. Providing this information to the market facilitates the efficient development of the network to best meet the needs of customers.

The DAPR is aligned with the requirements of clauses 5.13.2(b) and (c) of the National Electricity Rules (**NER**) and contains the detailed information set out in Schedule 5.8 of the NER. In addition, the DAPR contains information consistent with the requirements of section

¹ Transmission-distribution connection assets are discussed in the Transmission Connection Planning Report which is available on the CitiPower website at: <https://www.citipower.com.au/network-planning-and-projects/network-planning/>

3.5 of the Electricity Distribution Code, as published by the Essential Services Commission of Victoria.

1.1 Public consultation

CitiPower intends to hold a public forum to discuss this DAPR in early 2022. All interested stakeholders are welcome to attend, including interested parties on CitiPower's demand-side engagement register, and local councils.

CitiPower invites written submissions from interested parties to offer alternative proposals to defer or avoid the proposed works associated with network constraints. All submissions should address the technical characteristics of non-network options provided in this DAPR and include information listed in the demand-side engagement strategy.

We also welcome feedback or suggestions for improvement on the structure or content presented in this year's DAPR or Systems Limitations Template.

All written submissions or enquiries should be directed to:

- DMInterestedParties@CitiPower.com.au

Alternatively, CitiPower's postal address for enquiries and submissions is:

- CitiPower
Attention: Head of Network Planning and Development
Locked Bag 14090
Melbourne VIC 8001

2 Background

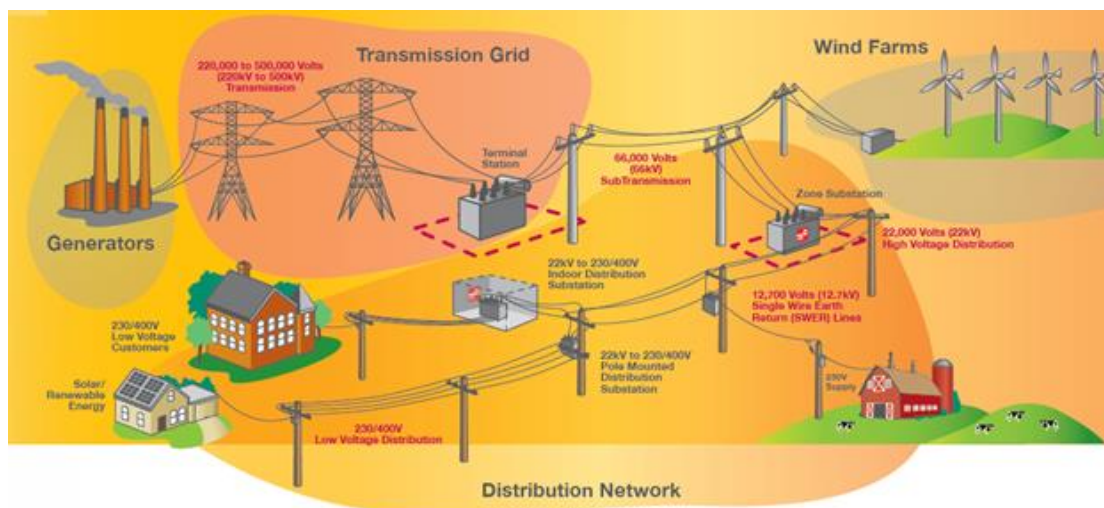
This chapter sets out background information on CitiPower Pty Ltd (**CitiPower**) and how it fits into the electricity supply chain.

2.1 Who we are

CitiPower is a regulated Distribution Network Service Provider (**DNSP**) within Victoria. CitiPower own the poles and wires which supply electricity to homes and businesses.

A high level picture of the electricity supply chain is shown in the diagram below.

Figure 2.1 The electricity supply chain



The distribution of electricity is one of four main stages in the supply of electricity to customers. The four main stages are:

- **Generation:** generation companies produce electricity from sources such as coal, wind or sun, and then compete to sell it in the wholesale National Electricity Market (**NEM**). The market is overseen by the Australian Energy Market Operator (**AEMO**), through the co-ordination of the interconnected electricity systems of Victoria, New South Wales, South Australia, Queensland, Tasmania and the Australian Capital Territory. It is recognised that a growing amount of generation is occurring at lower voltages including individual household photovoltaic (**PV**) arrays.
- **Transmission:** the transmission network transports electricity from generators at high voltage to five Victorian distribution networks. Victoria's transmission network also connects with the grids of New South Wales, Tasmania and South Australia.
- **Distribution:** distributors such as CitiPower convert electricity from the transmission network into lower voltages and deliver it to Victorian homes and businesses. The

major focus of distribution companies is developing and maintaining their networks to ensure a reliable supply of electricity is delivered to customers to the required quality of supply standards.

- **Retail:** the retail sector of the electricity market sells electricity and manages customer accounts. Retail companies issue customers' electricity bills, a portion of which includes regulated tariffs payable to transmission and distribution companies for transporting electricity along their respective networks.

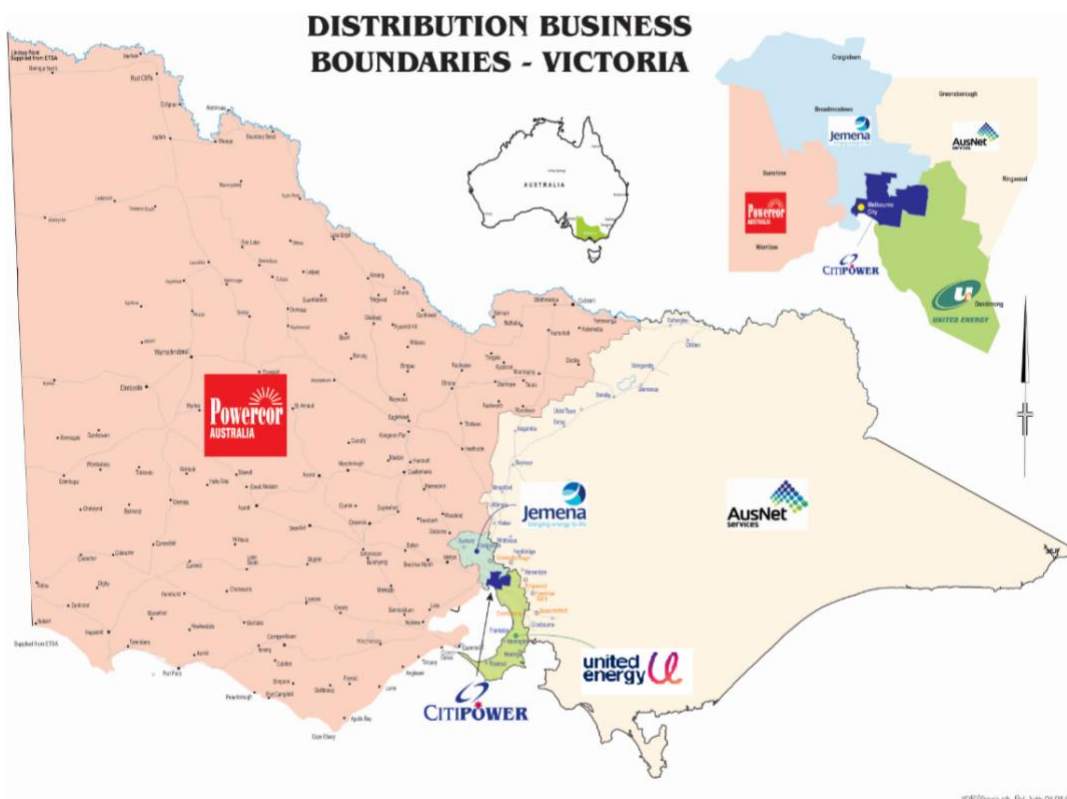
2.2 The five Victorian distributors

In the distribution stage of the supply chain, there are five businesses operating in Victoria. Each business owns and operates the electricity distribution network. CitiPower is one of those distribution businesses.

The CitiPower network provides electricity to customers in Melbourne's central business district (**CBD**) and inner suburbs, and supplies world-class cultural and sporting facilities such as Federation Square, the Melbourne Cricket Ground, the Victorian Arts Centre and Melbourne Park.

The coverage of CitiPower and other Victorian distributors is shown in the figure below.

Figure 2.2 CitiPower and other Victorian distribution areas



In Victoria, each DNSP has responsibility for planning the augmentation of their distribution network. In order to continue to provide efficient, secure and reliable supply to its customers, CitiPower must plan augmentation and asset replacement of the network to match network

capacity to customer demand. The need for augmentation is largely driven by customer peak demand growth, local generation (PV) and geographic shifts of demand due to urban redevelopment.

2.3 Delivering electricity to customers

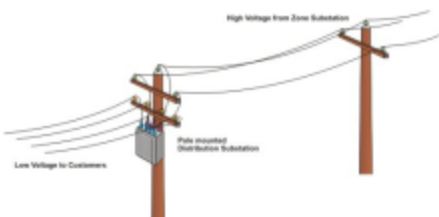
Power that is produced by large-scale generators is transmitted over the high voltage transmission network and is changed to a lower voltage before it can be used in the home or industry. This occurs in several stages, which are simplified below.



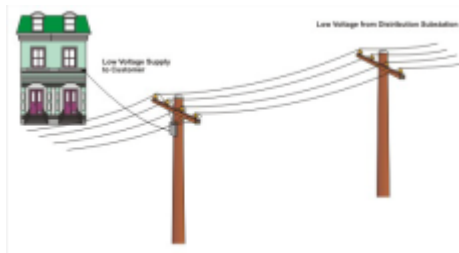
Firstly, the voltage of the electricity that is delivered to **terminal stations** is reduced by transformers. Typically in Victoria, most of the transmission lines operate at voltages of 500,000 volts (500 kilovolts or kV) or 220,000 volts (220kV). The transformer at the terminal station reduces the electricity voltage to 66kV. The CitiPower network is supplied from the terminal stations.



Second, CitiPower distributes the electricity on the **sub-transmission system** which is made up of large concrete or wooden power poles and powerlines, or sometimes underground powerlines. The sub-transmission system transports electricity to CitiPower's zone substations at 66kV or 22kV.



Third, at the **zone substation** the electricity voltage is converted from 66kV or 22kV, to 11kV or 6.6kV. Electricity at this voltage can then be distributed on smaller, lighter power poles.



Fourth, **high voltage distribution lines** (or distribution feeders) transfer the electricity from the zone substations to CitiPower's distribution substations.

Fifth, electricity is transformed to 400 / 230 volts at the **distribution substations** for supply to customers.

Finally, electricity is conveyed along the **low voltage distribution lines** to homes and businesses.

A growing amount of generation is occurring at lower voltages including individual customer level PV arrays.

2.4 Operating environment and asset statistics

CitiPower delivers electricity to around 345,000 homes and businesses in a 157 square kilometre area, or around 2,197 customers per square kilometre.

The CitiPower electricity network comprises a sub-transmission network which consists of predominately overhead lines which operate at 66kV with some at 22kV and a distribution network that generally operates at a voltage of 11kV with some 6.6kV. The overall network consists of around 55 per cent overhead lines and 45 per cent underground cables.

The sub-transmission network is supplied from a number of terminal stations which operate at a voltage of 220kV. This transmission network, including the terminal stations, is owned and operated by AusNet Services.

The sub-transmission network nominally operates at 66kV or 22kV and is often configured in loops to maximise reliability. The sub-transmission network supplies electricity to zone substations which then transform (step down) the voltage suitable for distribution to the surrounding area.

The distribution network consists of both overhead and underground lines connected to substations, switchgear, and other equipment to provide effective protection and control. Whilst the majority of the high voltage distribution system nominally operates at 11kV, there are some notable exceptions. For example, although they are being progressively decommissioned, 6.6kV distribution systems can still be found in areas of:

- Port Melbourne
- CBD
- North Melbourne
- Brunswick
- Fitzroy.

Distribution feeders are generally operated in a radial mode from their respective zone substation supply points with inter-feeder tie points which can be reconfigured to provide for load transfers and other operational contingencies.

The final supply to small consumers is provided through the low voltage distribution systems that nominally operate at 230 or 400 volts. These voltages are derived from distribution substations which are located throughout the distribution network and typically range in size from 200kVA to 8000kVA. Both overhead and underground low voltage reticulation, including service arrangements, complete the final connections to the low voltage consumer's points of supply. CitiPower's customer base comprises of high rise domestic and commercial customers, some industrial customers through to small domestic customers.

At the end of 2020-21FY, the CitiPower network comprised approximately:

Table 2.1 CitiPower network statistics

Item	Number / km
Poles	57,776
Overhead lines	4,173
Underground cables	3,343
Sub-transmission lines	108
Zone substation transformers	97
Distribution feeders	662
Distribution transformers	4,972

Appendix A shows maps that indicate location of CitiPower's zone substation assets and the connected terminal stations on a geographic basis.

3 Factors Impacting the Network

This chapter sets out the factors that may have a material impact on the CitiPower network:

- **demand:** changes in demand causing thermal capacity constraints, such as that caused from population growth resulting in new residential customers connecting to the network, new or changed business requirements for electricity or increased take-up of distributed energy resources and associated exports into the network
- **fault levels:** the increasing amount of embedded generation being directly connected to the CitiPower network is increasing the overall fault levels on the network which is reaching its fault level capacity in certain areas
- **voltage levels:** The rise of rooftop solar PV and a modern customers ability to not only receive power from the network but export power into it has challenged the range of voltages the network must operate within. Reorientating CitiPower's voltage control equipment and network topology is a current and enduring focus as customer exports and consumption continue to rapidly increase
- **other system security requirements:** there will be greater resilience in the network as the Melbourne CBD security of supply upgrade plan continues to be implemented. This plan requires significant investment to achieve coverage of the whole CBD
- **quality of supply:** as the energy transition continues to reshape how power is consumed and generated by customers, CitiPower actively works to ensure the quality of supply customers receive remains high and enables the satisfactory operation of customers new and existing appliances and equipment
- **ageing and potentially unreliable assets:** CitiPower utilises a Health Index as a guide to determining the condition, and therefore risk of the assets. Many of the ageing assets that are in deteriorated condition in the CitiPower network exist within the 22kV sub-transmission network and its associated zone substations
- **solar enablement:** CitiPower's 'Solar Enablement' program of works is focussed on limiting and mitigating issues related to high penetrations of solar PV and working to reorientate our network to support increasing power flows from and to our customers.

These factors are discussed in more detail below.

3.1 Demand

Changes in maximum demand on the network are driven by a range of factors. For example, this may include:

-
- **population growth:** increases in the number of residential customers connecting to the network
 - **economic growth:** changes in the demand from small, medium and large businesses and large industrial customers
 - **prices:** the price of electricity impacts the use of electricity
 - **weather:** the effect of temperature on demand largely due to temperature sensitive loads such as air-conditioners and heaters
 - **customer equipment and embedded generators:** the equipment that sits behind the customer meter including solar panels and batteries (which may mask the real demand behind the meter) causing capacity constraints, televisions, pool pumps, electric vehicles, solar panels, wind turbines, batteries, etc.

Forecasting for demand is discussed later in this document.

3.2 Fault levels

A fault is an event where an abnormally high current is developed as a result of a short circuit somewhere in the network. A fault may involve one or more line phases and ground, or may occur between line phases only. In a ground/ earth fault, charge flows into the earth or along a neutral or earth-return wire.

CitiPower estimates the prospective fault current to ensure it is within allowable limits of the electrical equipment installed, and to select and set the protective devices that can detect a fault condition. Devices such as circuit breakers, automatic circuit reclosers, sectionalisers, and fuses can act to break the fault current to protect the electrical plant, and avoid significant and sustained outages as a result of plant damage.

Fault levels are determined according to a number of factors including:

- generation of all sizes
- impedance of transmission and distribution network equipment
- load including motors
- voltage.

The following fault level limits are generally applied within CitiPower:

Table 3.1 Fault level limits

Voltage	Fault limit (kiloAmps, kA)
66kV	21.9 kA
22kV	13.1 kA for distribution lines
	26.2 kA for sub-transmission lines
11kV	18.4 kA
6.6kV	21.9 kA
<1kV	50 kA

Where fault levels are forecast to exceed the allowable fault level limits listed above, then fault level mitigation projects are initiated. This may involve, for example, introducing extra impedance into the network or separating network components that contribute to the fault such as opening the bus-tie circuit breakers at constrained zone substations to divide the fault current path.

Fault level mitigation programs are becoming increasingly common on the CitiPower network as the level of embedded generation being directly connected to the network increases. This is because of the increasing fault level contribution from local generators which the network was not designed for when originally conceived.

3.3 Voltage levels

Voltage levels are important for the operation of all electrical equipment, including home appliances with electric motors or compressors such as washing machines and refrigerators, or farming and other industrial equipment. These appliances are manufactured to operate within certain voltage threshold ranges.

Electricity distributors are obligated to maintain customer voltages within specified thresholds, and these are further discussed in section 16.2. Similarly, manufacturers can only supply such appliances and equipment that operate within the Australian Standards. Supply voltage at levels outside these limits could affect the performance or cause damage to the equipment as well as industry processes.

Voltage levels are affected by a number of factors including:

- generation of electricity into the network
- impedance of transmission and distribution network equipment
- length of sub-transmission or distribution feeders
- load
- capacitors in the network.

For CitiPower, the length of sub-transmission and distribution feeders in the network is relatively short compared with rural areas and this reduces the potential for customer voltage variations due to load however this situation is rapidly changing due to the impact of local solar generation which causes a sudden drop in voltage as the sun goes down and residential load increases.

CitiPower also installs additional voltage regulation equipment at zone substations where a bus-tie circuit breaker is opened as a result of fault level constraints.

3.4 System security

This section sets out other power system security requirements for the CitiPower network. In particular, it discusses the Melbourne CBD security of supply upgrade plan including:

- an outline of the capital and other works undertaken in 2021 to implement the plan
- an evaluation of whether the relevant security of supply objectives specified in the plan were achieved in 2021
- an outline of the capital and other works connected to the plan that is proposed to be carried out over the next 5 years.

The majority of works for the CBD upgrade plan was completed in 2016, and the new Waratah Place (**WP**) zone substation was commissioned in July 2020 with four new feeders. New works to complete coverage across the CBD are now required to be implemented.

3.4.1 2021 implementation of CBD security of supply upgrade plan

The Melbourne CBD security upgrade plan is an obligation under clause 3.1A of the Victorian Electricity Distribution Code. This obligation followed the publication of a Regulatory Test Final Report by CitiPower that economically justified the scope of works defined to upgrade the 66kV sub-transmission network in the Melbourne CBD to an 'N-1 Secure' standard.

The following Table 3.2 outlines the capital and other works carried out in 2021 as part of the plan. For completeness, the table also provides information on related project works which, while not part of the scope of security works, are required as part of the overall network development scenario to enable the security upgrade works to be completed.

Table 3.2 2021 CBD Upgrade plan works

Description of capital works	2021 Progress	Evaluation of 2021 against objectives
<i>Transmission, Capacity Related</i>		

Description of capital works	2021 Progress	Evaluation of 2021 against objectives
Establish a 66kV point of supply at Brunswick terminal station (BTS), including 3 x 220/66kV transformers, associated switchgear and protection	Completed	Achieved target
<i>Distribution, Capacity Related</i>		
Establish 2 x 66kV high capacity cables from BTS to Bouverie/Queensberry (BQ) zone substation, and associated protection	Completed	Achieved revised targets
BQ zone substation refurbishment. Install 9 x 66kV circuit breakers, 2 x 66/11kV transformers and associated switchgear and protection	Completed	Achieved revised targets
<i>Distribution, Security Enhancement</i>		
Establish 66kV connection circuit breakers, and associated protection at BTS	Completed	Achieved revised targets
Establish a 66kV high capacity cable from BTS to Victoria Market (VM) zone substation, and associated protection	Completed	Achieved revised targets
Establish 2 x 66kV high capacity cables from BQ to VM, and associated protection	Completed	Achieved revised targets
VM zone substation refurbishment. Install 19 x 66kV	Completed	Achieved revised targets

Description of capital works	2021 Progress	Evaluation of 2021 against objectives
circuit breakers and associated protection		
Waratah Place (W) , to be renamed (WP) zone substation re-build. Install 16 x 66kV circuit breakers, 2 x 66/11kV transformers and associated switchgear and protection	Completed	Achieved revised targets
Establish 2 x 66kV high capacity cables from BQ to new WP zone substation, and associated protection	Completed	Achieved revised targets
Re-configure existing VM to W and W to Celestial Avenue (WA) 66kV cables to establish one VM to WA 66kV cable and by-pass W zone substation	Completed	Achieved revised targets
McIllwraith Place (MP) zone substation 66kV bus tie switch / re-configuration	Completed	Achieved revised targets

3.4.2 Future CBD upgrade works

Due to load growth in the southwest of Melbourne CBD, which is mainly supplied by zone substations Little Bourke (JA) and Little Queen (LQ), CitiPower is planning to rebuild the existing zone substation at Tavistock Place (TP). Elements of the new zone substation are required as part of the Melbourne CBD security program which seeks to increase resilience into the 66 kV sub-transmission network given the critical nature of reliable electricity supply to the area. The new TP zone substation with new distribution feeders will provide sufficient transfer capacity at 11 kV to JA and LQ to meet the requirements of 'N-1 Secure'.

Table 3.3 below presents the project timeline for the CBD security of supply project.

Table 3.3 Future CBD upgrade works

Description of capital works	2022	2023	2024	2025	2026
<i>Distribution, Security Enhancement</i>					
Establish Tavistock Place (TP) zone substation at 66kV	X	X	X	X	
Transfer load from Little Queen (LQ) zone substation to TP					X
Transfer load from Little Bourke (JA) to TP					X

3.5 Quality of supply to other network users

As the energy transition continues to reshape how power is consumed and generated by our customer the quality of supply they receive is an increasing focus for CitiPower.

To support its customers, CitiPower:

- may carry out system studies on a case-by-case basis as part of the new customer connection process
- responds supportively to customers who are experiencing issues with the electrical supply to their property
- proactively monitors quality of supply to address emerging issues before customers experience adverse power supply.

3.6 Ageing and potentially unreliable assets

CitiPower carries out routine maintenance on all its assets to reduce the probability of plant failure, and ensures they are fit for operation.

There are two key areas of ageing and potentially unreliable assets that are a priority for CitiPower:

-
- assets with a high Health Index
 - assets in the 22kV sub-transmission network.

These are further discussed below.

3.6.1 Health Index

CitiPower uses the Condition Based Risk Management (**CBRM**) methodology to plan any required interventions to manage risks associated with the performance of major items of plant and equipment.

The model is an ageing algorithm that takes into account a range of inputs including:

- condition assessment data, such as transformer oil condition
- environmental factors, such as whether the assets are located indoors or outdoors, or coastal areas
- operating factors, such as the load utilisation, frequency of use and load profiles that the asset is supplying.

These factors are combined to produce a Health Index for each asset in a range from 0 to 10, where 0 is a new asset and 10 represents end of life. The Health Index provides a means of comparing similar assets in terms of their calculated probability of failure.

CitiPower will closely monitor assets with a Health Index in the range 5 to 7 to determine options for intervention, including replacement or retirement, in the context of energy at risk. Interventions are planned when an asset's Health Index exceeds 5.5 and intervention prioritised when an asset's Health Index exceeds 7.

A Health Index profile gives an immediate appreciation of the condition of all assets in a group and an understanding of the future condition of the assets. For the purposes of this DAPR, the Health Index of some assets has been provided where CitiPower has assessed the risk to be sufficient to require intervention in the next five years.

As part of the CBRM process, a consequence of failure of the asset is also calculated. This assesses the consequence to customers due to loss of supply. The loss of a large amount of load (in MW) to a large industrial customer or to a large number of residential customers will indicate a high consequence of failure. This consequence of failure consists of four elements:

- network performance
- safety
- financial
- environment

The risk to CitiPower is calculated by combining the probability of failure of the asset and the consequence of failure of the asset. CBRM is used to calculate how the risk will change in future years and determine the optimum timing for any intervention.

3.6.2 Replacement of 22kV sub-transmission network

The 22kV sub-transmission network contains many ageing assets that are in a deteriorated condition. These assets include transformers, underground sub transmission oil/paper cables and indoor switchgear within existing zone substations. CitiPower reviews the Health Indexes of these assets as a factor to assist in determining whether or not to trigger intervention.

CitiPower is planning to continue replacing the 22kV sub-transmission network by upgrading zone substations to the 66kV sub-transmission network or transferring the zone substation load to an existing 66kV zone substation. We are also working with AusNet Services to align our works programs so that the removal of 220/22kV transmission assets are coordinated with our 22kV sub-transmission upgrades (see section 10.1). Operation of the sub-transmission network at the higher voltages also reduces the amount of distribution losses from the network. At the same time CitiPower intends to upgrade the associated 6.6kV distribution network to 11kV.

3.6.3 Replacement of 6.6kV high voltage feeder network

A number of the older zone substations have secondary voltages of 6.6kV, which is inconsistent with the current 11kV standard in the CitiPower network. These non-standard 6.6kV secondary voltages have many technical limitations when compared with the standard 11kV secondary voltage including a limited loading capability. Having 6.6kV distribution feeders limits system flexibility with regard to load transfers and with encroachment by the 11kV network has created islands within the 6.6kV network which are now not able to be backed up from the surrounding 11kV network.

Now that many plant items in these older zone substations are reaching their end of life, it is time to consider a planned upgrade to 11kV to eliminate the limitations the 6.6kV system imposes. This will renew these areas, enabling higher loads to be supported and providing backup possibilities from surrounding areas. This is especially important for a number of urban renewal projects occurring in these older areas of CitiPower.

3.7 Solar Enablement

Distributed Energy Resources (particularly solar PV) connected to the network are creating voltage variations, which are expected to significantly increase, in part due to penetration levels reaching a tipping point and a new Victorian Government policy subsidising solar PV for up to 650,000 households over 10 years.

In areas with a higher proportion of solar customers, solar PV exports are causing the localised network voltage to rise during daylight hours. This can affect the quality of electricity supply to all customers in the area, trip solar customers' solar PV systems (from export and in-home-use) and raise network voltages above the limits set by the Electricity Distribution Code (**Code**).

Solar PV exports also have the potential to create capacity constraint concerns on the LV network. This is due to the increasing solar PV penetration, increasing average solar PV system sizes (to a point where a customer's export capacity can exceed their load

requirements) and the relatively low diversity of exports when compared to load diversity, for which the network was traditionally designed to accommodate.

CitiPower's delivery of its 5-year 'Solar Enablement' program of works to limit these issues is progressing and includes:

- implementation of a Dynamic Voltage Management System planned with commissioning to progressively occur from January to June 2022 at the majority of CitiPower zone substations. This will enable increased solar hosting capacity by dynamically adjusting system voltages based on feedback from AMI meters installed at each customer premise.
- completion of remedial interventions such as phase rebalancing, distribution transformer tapping, distribution transformer replacement and undertaking conductor works and replacements.

The CitiPower solar network optimisation project was initiated and delivered in 2021. This involved network interventions across the CitiPower network.

Further works involving high and low voltage interventions and system upgrade activities are planned for 2022, including:

- continued engagement with manufacturers, installers, and customers that have identified issues, to rectify solar PV installations and inverter setting issues, and improve installation compliance going forward
- maximising the capability for existing solar PV installations to export energy by considering the effects of any newly proposed solar PV installations on the network.

3.8 Distribution System Operator (DSO) enhanced capability

To respond to the future challenges of the network at least cost it is recognised that CitiPower needs to implement and support new capabilities under an enhanced DSO role. Information Technology (IT) investments in this area have been articulated in Chapter 18 Information Technology and Communication Systems. These capabilities are broadly around the workstreams of:

- enabling DER export and increasing hosting capacity whilst addressing minimum demand and other system security obligations that may be placed on the distributor
- utilising batteries to manage constraints and value stacking arrangements with third parties to demonstrate multiple benefits
- enabling competition for non-network solutions through expanded platforms for sharing network constraints
- develop Dynamic Operating Envelope capability that is flexible to more dynamically manage the network and enable third party service offerings on the distribution network

Chapter 17.2 details the specific projects that CitiPower is delivering in terms of demand management and non-network solutions.

4 Network Planning Standards

This chapter sets out the process by which CitiPower identifies constraints in its network.

4.1 Approaches to planning standards

In general there are two different approaches to network planning.

Deterministic planning standards: this approach calls for zero interruptions to customer supply following any single outage of a network element, such as a transformer. In this scenario any failure or outage of individual network elements (known as the “N-1” condition) can be tolerated without customer impact due to sufficient resilience built into the distribution network. A strict use of this approach may lead to inefficient network investment as resilience is built into the network irrespective of the cost of the likely interruption to the network customers, or use of alternative options.

Probabilistic planning approach: the deterministic N-1 criterion is relaxed under this approach, and simulation studies are undertaken to assess the amount of energy that would not be supplied if an element of the network is out of service. As such, the consideration of energy not served may lead to the deferral of projects that would otherwise be undertaken using a deterministic approach. This is because:

- under a probabilistic approach, there are conditions under which all the load cannot be supplied with a network element out of service (hence the N-1 criterion is not met), however
- the actual load at risk may be very small when considering the probability of a forced outage of a particular element of the sub-transmission network

In addition, the probabilistic approach assesses load at risk under system normal conditions (known as the “N” condition). This is where all assets are operating but load exceeds the total capacity. Contingency transfers may be used to mitigate load at risk in the interim period until an augmentation is completed.

4.2 Application of the probabilistic approach to planning

CitiPower adopts a probabilistic approach to planning its zone substation and sub-transmission asset augmentations. The probabilistic planning approach involves estimating the probability of an outage occurring within the peak loading season, and weighting the costs of such an occurrence by its probability, to assess:

- the expected cost that will be incurred if no action is taken to address an emerging constraint, and therefore;
- whether it is economic to augment the network capacity to reduce expected supply interruptions.

The quantity and value of energy at risk (which is discussed in section 6.1) is a critical parameter in assessing a prospective network investment or other action in response to an emerging constraint. Probabilistic network planning aims to ensure that an economic balance is struck between:

- the cost of providing additional network capacity to remove constraints
- the cost of having some exposure to loading levels beyond the network's capability

In other words, recognising that very extreme loading conditions may occur for only a few hours in each year, it may be uneconomic to provide additional capacity to cover the possibility that an outage of an item of network plant may occur under conditions of extreme loading. The probabilistic approach requires expenditure to be justified with reference to the expected benefits of lower unserved energy.

This approach provides a reasonable estimate of the expected net present value to consumers of network augmentation for planning purposes. However, implicit in its use is acceptance of the risk that there may be circumstances (such as the loss of a transformer at a zone substation during a period of high demand) when the available network capacity will be insufficient to meet actual demand and significant load shedding could be required. The extent to which investment should be committed to mitigate that risk is ultimately a matter of judgment, having regard to:

- the results of studies of possible outcomes, and the inherent uncertainty of those outcomes
- the potential costs and other impacts that may be associated with very low probability events, such as single or coincident transformer outages at times of peak demand, and catastrophic equipment failure leading to extended periods of plant non-availability
- the availability and technical feasibility of cost-effective contingency plans and other arrangements for management and mitigation of risk

4.3 Application of the CBD Secure approach to planning in the Melbourne CBD

CitiPower adopts a modified probabilistic approach to planning its Central City zone substation and sub-transmission asset augmentations. This standard referred to as CBD Secure requires that for any loss of a sub transmission cable, no load is lost. Also it requires adequate transfers are available such that following a 30 minute interval to allow for transfers, a second sub transmission cable can fail without loss of load.

5 Forecasting Demand

This chapter sets out the methodology and assumptions for calculating historical and forecast levels of demand for each existing zone substation and sub-transmission system. These forecasts are used to identify potential future constraints in the network.

Please note that information relating to transmission-distribution connection points are provided in a separate report entitled the “Transmission Connection Planning Report” and available on the CitiPower website.²

5.1 Maximum demand forecasts

CitiPower has set out its forecasts for maximum demand for each existing zone substation and sub-transmission system in the Forecast Load Sheet.

5.2 Zone substation methodology

This subsection sets out the methodology and information used to calculate the demand forecasts and related information that is referred to in the Forecast Load Sheet and System Limitation Reports.

5.2.1 Historical demand

Historical demand is calculated in Mega Volt Ampere (**MVA**) and is based on actual load and demand values recorded across the distribution network.

As peak demand in CitiPower is very temperature and weather dependent, the actual peak demand values referred to in the Forecast Load Sheet are normalised for the purpose of forecasting, in accordance with the relevant weather conditions experienced across any given summer loading period. The correction enables the underlying peak demand growth year-by-year to be estimated, which is used in making future forecast and investment decisions.

The temperature correction seeks to ascertain the “50th percentile maximum demand”. The 50th percentile demand represents the peak demand on the basis of a normal season (summer and winter). For summer, it relates to a maximum average load that will be exceeded, on average, once every two years. By definition therefore, actual demand in any given year has a 50 per cent probability of being higher than the 50th percentile demand

² <https://www.citipower.com.au/network-planning-and-projects/network-planning/>

forecast.³ The 50th percentile forecast can therefore be considered to be a forecast of the “most-likely” level of demand, bearing in mind that actual demand will vary depending on temperature and other factors. It is often referred to as 50 per cent probability of exceedance (PoE).

5.2.2 Forecast demand

Historical demand values taking into account local generation inputs are trended forward and added to known and predicted loads that are to be connected to the network. This includes taking into account the number of customer connections and the calculated total output of known embedded generating units.

CitiPower has taken into account information collected from across the business relating to the load requirements of our customers, and the timing of those loads. This includes population growth and economic factors as well as information on the estimated load requirements for planned, committed and developments under-construction across the CitiPower service area. These bottom-up forecasts for demand have been reconciled with top-down independent econometric forecasts for CitiPower as a whole.

These forecasts are set out in the Forecast Load Sheet.

5.2.3 Definitions for zone substation forecast tables

The Forecast Load Sheet contains other statistics of relevance to each zone substation, including:

- **Nameplate (N) rating:** this provides the maximum capacity of the zone substation according to the equipment in place;
- **Cyclic N-1 rating:** this assumes that the load follows a daily pattern and is calculated using load curves appropriate to the season and assuming the outage of one transformer. This is also known as the “firm” rating;
- **Hours load is $\geq$ 95% of maximum demand (MD):** based on at least the most recent 12 months of data, assesses the load duration curve and the total hours during the year that the load is greater than or equal to 95 per cent of maximum demand;
- **Station power factor at maximum demand (MD):** based on the most recent maximum demand achieved in a season at the zone substation, this is a measure of how effectively the current is being converted into output and is also a good indicator of the effect of the load current on the efficiency of the supply system. It is calculated as a ratio of real power and apparent power and is used to inform load forecasts. A power factor of:
 - less than one: indicates a lagging or leading current in the supply system which may need correction, such as by increasing or reducing capacitors at the zone substation;

³ Consequently there is also a 50% probability that demand will not reach forecast.

-
- one: efficient loading of the zone substation
 - **Load transfers:** forecasts the available capacity of adjacent zone substations and feeder connections to take load away from the zone substation in emergency situations; and
 - **Generation capacity:** calculates the total capacity of all embedded generation units that have been connected to the zone substation at the date of this report. Summation of generation above and below 1MW is provided.

5.3 Sub-transmission line methodology

This section sets out the methodology for calculating the historical and forecast maximum demands for the sub-transmission lines.

5.3.1 Historical demand

The sub-transmission line historical N-1 maximum demand loads for different line configurations are determined using a powerflow analysis tool called Power System Simulator for Engineering (**PSS/E**).

The tool models the sub-transmission line from the terminal station to the zone substation to determine the theoretical N-1 maximum demand, by utilising historical actual loads and assessing:

- system impedances
- transformer tapping ratios, which are used to regulate the transformer voltages
- capacitor banks
- other technical factors relevant to the operation of the system

The historical maximum demand data for the relevant zone substations is applied to the load flow analysis to enable calculation of the theoretical N-1 maximum demand of the sub-transmission line.

The zone substation forecast maximum demands are diversified to the expected zone substation loads at the time of the respective sub-transmission loop/ line maximum demand. Historical diversity factors are derived and applied.

The data is used to assess the maximum demand in the worst case “N-1” conditions. This is for a single contingency condition where there is the loss of an element in the power system, in particular the loss of another associated sub-transmission line. For a zone substation the load is identical whether the zone substation is operating under N or N-1 (loss of a transformer). Therefore the N-1 cyclic rating is used to compare against the load forecast. However for the loss of a sub-transmission line, other associated lines are loaded more heavily so it is appropriate to consider the N-1 condition for the forecast and compare to the line rating.

5.3.2 Forecast demand

Similar to the sub-transmission line historical maximum demand loads, bottom-up forecasts for maximum demand are predicted utilising a powerflow analysis tool, PSS/E for different line configurations.

The present sub-transmission system is modelled from the terminal stations to the zone substations, taking into account system impedances, transformer tapping ratios, voltage settings, capacitor banks and other relevant technical factors.

The reconciled maximum demand forecasts at each zone substation are used in calculating the maximum demand forecasts for the sub-transmission lines. As discussed in section 5.2 above, the bottom-up forecasts for demand at each zone substation have been reconciled with top-down independent econometric forecasts.

The zone substation forecast maximum demands are diversified based on the historical diversity factors mentioned above.

The data is used to forecast the maximum demand under “N-1” conditions. These forecasts are referred to in the Forecast Load Sheet.

5.3.3 Definitions for sub-transmission line forecast tables

The Forecast Load Sheet refers to other statistics of relevance to each sub-transmission line, including:

- **Line rating:** this provides the maximum capacity of the sub-transmission line as measured by its current and expressed in MVA
- **Hours load is $\geq$ 95% of maximum demand (MD):** based on at least the most recent 12 months of data, assesses the load duration curve and the total hours during the year that the load is greater than or equal to 95 per cent of maximum demand
- **Power factor at maximum demand (MD):** based on historical data, is a measure of how effectively the current is being converted into output and is also a good indicator of the effect of the load current on the efficiency of the supply system. It is calculated as a ratio of real power and apparent power and is used to inform load forecasts. A power factor of:
 - less than one: indicates a lagging or leading current in the supply system which may need correction, such as by increasing or reducing capacitors at the zone substation
 - one: efficient loading of the zone substation
- **Load transfers:** forecasts the available capacity of alternative sub-transmission lines that can carry electricity to the zone substation in emergency situations
- **Generation capacity:** calculates the total capacity of all embedded generation units that have been directly connected to the sub-transmission line at the date of this report

5.4 Primary distribution feeders

This section sets out the methodology for calculating the forecast maximum demands for the primary distribution feeders.

5.4.1 Forecast demand

Primary distribution feeder maximum demand forecasts are calculated using a similar methodology to our zone substation forecasts. The historical feeder demand values are trended forward using the underlying feeder growth rate including known or predicted loads that are forecast for connection. Temperature correction and top down reconciliation occurs on the feeder and zone substation forecasts and is therefore inherent in the sub-transmission forecasts.

6 Approach to Risk Assessment

This chapter outlines the high level process by which CitiPower calculates the risk associated with the expected balance between capacity and demand over the forecast period for zone substations and sub-transmission lines.

This process provides a means of identifying those stations or lines where more detailed analyses of risks and options for remedial action are required.

6.1 Energy at risk

As discussed in section 4.1, probabilistic network planning aims to strike an economic balance between:

- the cost of providing additional network capacity to remove any constraints
- the potential cost of having some exposure to loading levels beyond the network's firm capability

A key element of this assessment for each zone substation and sub-transmission line is “energy at risk”, which is an estimate of the amount of energy that would not be supplied if one transformer or a sub-transmission line was out of service during the critical loading period(s).

For zone substations, **energy at risk** is defined as, the amount of energy that would not be supplied from a zone substation if a major outage⁴ of a transformer occurs at that station in that particular year, the outage has a mean duration of 2.6 months during the peak load period and no other mitigation action is taken.

This statistic provides an indication of magnitude of loss of load that would arise in the unlikely event of a major outage of a transformer without taking into account planned augmentation or operational action, such as load transfers to other supply points, to mitigate the impact of the outage.

For sub-transmission lines, the same definition applies however, the mean duration of an outage due to a significant failure is 8 hours for overhead sub-transmission lines and 1 week for underground sub-transmission lines.

⁴ The term 'Major Outage' refers to an outage that has a duration of 2.6 months, typically due to a significant failure within the transformer.

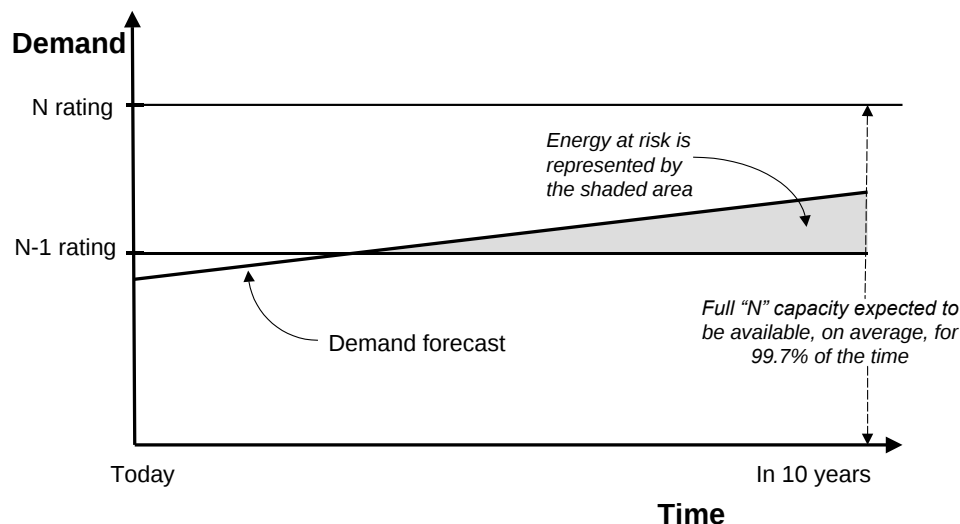
Estimates of energy at risk are based on the 50th percentile demand forecasts, which were discussed in sections 5.2 and 5.3.

6.2 Interpreting “energy at risk”

As noted above, “energy at risk” is an estimate of the amount of energy that would not be supplied if one transformer or sub-transmission line was out of service during the peak loading period(s).

The capability of a zone substation with one transformer out of service is referred to as its “N minus 1” rating. The capability of the station with all transformers in service is referred to as its “N” rating. The relationship between the N and N-1 cyclic ratings of a station and the energy at risk is depicted in Figure 6.1 below.

Figure 6.1 Relationship between N, N-1 cyclic ratings and energy at risk



Note that:

- Under normal operating conditions, there will typically be more than adequate zone substation capacity to supply all demand
- The risk of prolonged outages of a zone substation transformer leading to load interruption is typically very low
- The capability of a sub-transmission line network with one line out of service is referred to as the (N-1) condition for that sub-transmission network.
- Under normal operating conditions, there will typically be more than adequate line capacity to supply all demand
- The risk of prolonged outages of a sub-transmission line leading to load interruption is typically very low and is dependent upon the length of line exposed and the environment in which the line operates

In estimating the expected cost of plant outages, this report considers the first order contingency condition (“N-1”) only.

6.3 Valuing supply reliability from the customer's perspective

For large augmentation or replacement projects over \$6 million that are subject to a Regulatory Investment Test for Distribution (**RIT-D**), CitiPower will undertake a detailed assessment process to determine whether or not to proceed with the augmentation.

In order to determine the economically optimal level and configuration of distribution capacity (and hence the supply reliability that will be delivered to customers), it is necessary to place a value on supply reliability from the customer's perspective.

Estimating the marginal value to customers of reliability is inherently difficult, and ultimately requires the application of some judgement. Nonetheless, there is information available (principally, surveys designed to estimate the costs faced by consumers as a result of electricity supply interruptions) that provides a guide as to the likely value.

A rule change in July 2018 made the Australian Energy Regulator (AER) responsible for determining the values different customers place on having a reliable electricity supply. The AER subsequently developed an updated methodology for deriving Value of Customer Reliability (**VCR**) values and published new VCRs in December 2019. The applicable CitiPower VCR values from this publication are as per Table 6.3 below.

Table 6.3 Values of customer reliability

Sector	VCR for 2020 (\$/kWh)
Residential	\$21.58
Commercial	\$44.83
Agricultural	\$38.13
Industrial (<10MVA)	\$64.23

These values are multiplied by the relative weighting of each sector at the zone substation or for the sub-transmission line, and a composite single value of customer reliability is estimated.

This data used to calculate the economic benefit of undertaking an augmentation, and where the net present value of the benefits outweighs the costs, and is superior to other options, CitiPower will proceed with the works.

CitiPower notes that there has been a reduction in the VCR estimates for the residential, commercial and agricultural sectors while a significant increase for the industrial sector compared to the results of the 2019 VCR study, which was published in AEMO's 2019 Application Guide.

From a planning perspective, it is appropriate for CitiPower to have regard to the latest available VCR estimates. It is also important to recognise, however, that all methods for estimating VCR are prone to error and uncertainty as they represent customer groups as one of 4 generic classifications.

7 Zone Substations Review

This chapter reviews the zone substations where further investigation into the balance between capacity and demand over the next five years is warranted, taking into account the:

- forecasts for maximum demand to 2026
- summer and winter cyclic N-1 ratings for each substation

Where the zone substations are forecast to operate with maximum demands greater than 5 per cent above their firm summer or winter rating during 2022, then this section assesses the energy at risk for those assets.

If the energy at risk assessment is material, then CitiPower sets out possible options to address the system limitations. CitiPower may employ the use of contingency load transfers to mitigate the system limitations although this will not always address the entire load at risk at times of maximum demand. At other times of lower load the available transfers may be greater. As a result, the use of load transfers under contingency situations may imply a short interruption of supply for customers to protect network elements from damage and enable all available load transfers to take place.

Non-network providers may wish to review the limitations and consider whether alternative solutions to those set out in the analysis may be suitable. Solutions may also address sub-transmission constraints at the same time. The annualised cost of the preferred network option provides a broad indication of the maximum potential value available to proponents of non-network solutions in deferring or avoiding network augmentation. However, it should be noted that the value of a non-network solution depends on the extent to which it defers or avoids a network augmentation, and the expected timing of the network augmentation.

CitiPower notes that all other zone substations that are not specifically mentioned below either have loadings below the relevant rating or the loading above the relevant rating is minimal and can be addressed using load transfer capability via the distribution network to adjacent zone substations. In these cases, all customers can be supplied following the failure or outage of an individual network element.

Finally, zone substations that are proposed to be commissioned during the forward planning period are also discussed.

7.1 Zone substations with forecast system limitations overview

CitiPower proposes to augment the zone substations listed in the table during the forward planning period.

Table 7.1 Proposed zone substation augmentations

Zone substation	Description	Direct cost estimate (\$ million)				
		2022	2023	2024	2025	2026
BK	Offload to WB and decommission				0.6	0.9
BQ	Install a third transformer (55MVA)			1.1	2.9	
C	Offload to WB and decommission	1.4				
DA	WMTS 22kV retirement – Upgrade DA site to 66kV	3.9				
E	Offload to WG and decommission					0.1
F	Offload to CW and decommission		0.9	5.6	5.7	
PM	Offload to WG and decommission					0.1
TP	Rebuild TP to 66/11kV (Including 66kV lines)		0.2	2.8	12.0	12.0

The excel based detailed system limitation reports can be found at the link below by searching for zone substation system limitation report:

<https://spaces.hightail.com/space/UaPnYI6yeV>

CitiPower intends to undertake replacement-driven augmentation projects over the forecast period, including:

- upgrading West Brunswick (**WB**) zone substation to offload the Brunswick (**C**) zone substation, based on the poor condition of C
- conducting a program of works to enable decommissioning of the 22kV sub-transmission network served from West Melbourne terminal station (**WMTS**)
- offloading of Brunswick (**BK**) and Fitzroy (**F**) zone substations and conversion of their distribution areas from 6.6kV to 11kV
- constructing Tavistock Place (**TP**) zone substation to support partially offloading of Little Bourke (**JA**) and Little Queen (**LQ**) zone substations for CBD Security of supply
- commencing works to enable offloading of Port Melbourne (**PM**) and Fishermans Bend (**E**) zone substations and conversion of their distribution area from 6.6kV to 11kV
- commencing works to augment Westgate (**WG**) zone substation to support the offloading of PM and E

The replacement-driven augmentation projects are discussed in section 14.1. The options and analysis are explained below.

7.2 Zone substations with forecast system limitations

7.2.1 E (Fishermans Bend) zone substation

The zone substation in Fishermen's Bend (E) is served by two sub-transmission lines from Fisherman Bend Terminal station (FBTS). The zone substation supplies areas of Fisherman's Bend and Port Melbourne.

Currently, the E zone substation is comprised of one 10/13.5 MVA transformer operating at 66/6.6kV. The maximum demand is forecast to be 3.6 MVA in Summer 2021/2022. Whilst the maximum demand forecast is within station N rating, there is 3.6 MVA load at risk for the duration of a transformer outage and it will not be able to supply all customers from the zone substation.

To address the system constraint at E zone substation, CitiPower considers that the following network solutions could be implemented to managed the load at risk:

- contingency plan to transfer load away via 6.6kV links to adjacent zone substation of Westgate (WG) up to maximum transfer of 1.6 MVA
- offload E to Westage (WG) zone substation and convert the 6.6kV feeders to 11kV for an estimated cost of \$2.3 million as part of CitiPower's strategy to convert the 6.6kV network in Port Melbourne area to 11kV

CitiPower's preferred option is to offload E to WG and convert the 6.6kV feeders to 11kV by end of 2027 to meet the load growth in Port Melbourne area as well as to reduce the load at risk for an N-1 event.

7.2.2 Fitzroy (F) zone substation

The zone substation in Fitzroy (**F**) is served by two sub-transmission lines from Brunswick terminal station 22kV (**BTS22**). This zone substation supplies areas of Fitzroy, which is a mixed-use area, with residential, commercial and a small number of industrial customers.

Currently, F zone substation is comprised of two 10/13MVA transformers operating at 22/6.6kV. The maximum demand is forecast to be 13.7 MVA in summer 2021/22 which will exceed the N-1 cyclic capacity of 13.0 MVA.

CitiPower estimates that in 2026 there will be 1.6 MVA of load at risk and for 13 hours it will not be able to supply all customers from the zone substation if there is a failure of one of the transformers at F. That is, it would not be able to supply all customers during high load periods following the loss of a transformer.

To address the anticipated system constraint at F zone substation, CitiPower considers that the following network solutions could be implemented to manage the load at risk:

- contingency plan to transfer load away via 6.6kV links to adjacent zone substations of Collingwood (**CW**) and Brunswick (**C**) up to a maximum transfer capacity of 4.6 MVA, the available transfer is limited as only one CW feeder operates at 6.6kV via an auto-transformer and zone substation C is to be offloaded and retired by end of 2025
- offload F to CW and convert the 6.6kV feeders to 11kV to enable more transfers for an estimated cost of \$13.3 million.

CitiPower's preferred option is to offload F and convert the 6.6kV feeders to 11kV by end of 2026 to meet the load growth in Fitzroy and Collingwood area as well as to reduce the load at risk for an N-1 event.

7.2.3 Deepdene (L) zone substation

The zone substation in Deepdene (**L**) is served by sub-transmission lines from the Templestowe Terminal Station (**TSTS**). It supplies the Balwyn, Canterbury and Kew areas.

Currently, the L zone substation is comprised of two 20/30MVA transformers operating at 66/11kV. The maximum demand is forecast to be 40.7 MVA in summer 2021/22 which will exceed the N-1 cyclic capacity of 32.1 MVA.

CitiPower has estimated the magnitude and impact of loss of load by considering the energy at risk and the annual hours at risk. These estimates, exclude any planned augmentation or operational response such as load transfers to mitigate the impact of an outage.

For example in 2026, CitiPower estimates that there will be 5.3 MVA of load at risk and for 12 hours of the year it would not be able to supply all customers from the zone substation if there is a failure of one of the transformers at L. That is, it would not be able to supply all customers during high load periods following the loss of a transformer.

To address the anticipated system constraint at the L zone substation, CitiPower considers that the following network solutions could be implemented to manage the load at risk:

- contingency plan to transfer load away via 11kV links to adjacent zone substations of Kew **(Q)**, Riversdale **(RD)** and Camberwell **(CL)** up to a maximum transfer capacity of 14.4 MVA
- install a third transformer at L for an estimated cost of \$3.6 million.

CitiPower's preferred option is to establish a third transformer at L. However given that the forecast annual hours at risk is low, this project is not expected to occur during the forecast period. Although the expected demand will exceed the station's N-1 cyclic rating, the use of contingency load transfers will mitigate the risk in the interim period.

7.2.4 Kew **(Q)** zone substation

The zone substation in Kew **(Q)** is served by sub-transmission lines from the Templestowe Terminal Station **(TSTS)**. It supplies the Kew area.

Currently, the Q zone substation is comprised of two 20/30MVA transformers operating at 66/11kV. The maximum demand is forecast to be 36.8 MVA in summer 2021/22 which will exceed the N-1 cyclic capacity of 27.2MVA.

CitiPower has estimated the magnitude and impact of loss of load by considering the energy at risk and the annual hours at risk. These estimates, exclude any planned augmentation or operational response such as load transfers to mitigate the impact of an outage.

For example in 2026, CitiPower estimates there will be 7.2 MVA of load at risk and for 30 hours of the year it would not be able to supply all customers from the zone substation if there is a failure of one of the transformers at Q. That is, it would not be able to supply all customers during high load periods following the loss of a transformer.

To address the anticipated system constraint at the Q zone substation, CitiPower considers that the following network solutions could be implemented to manage the load at risk:

- contingency plan to transfer load away via 11kV links to adjacent zone substations of North Richmond **(NR)**, Deepdene **(L)** and Camberwell **(CL)** up to a maximum transfer capacity of 7.2MVA
- establish a third transformer at Q for an estimated cost of \$3.6 million
- establish a third transformer at L and permanently transfer load away from Q to L at an estimated cost of \$4.6 million

CitiPower's preferred option is to install a third transformer at L and permanently transfer load away from Q to L. However given that the forecast annual hours at risk is low, this project is not expected to occur during the forecast period. Although the expected demand will exceed the station's N-1 cyclic rating, the use of contingency load transfers will mitigate the risk in the interim period.

7.2.5 Riversdale (RD) zone substation

The zone substation in Riversdale (**RD**) is served by sub-transmission lines from the Springvale Terminal Station (**SVTS**). It supplies the Camberwell area.

Currently, the RD zone substation is comprised of two 20/30MVA transformers operating at 66/11kV. The maximum demand is forecast to be 35.8 MVA in summer 2021/22 which will exceed the N-1 cyclic capacity of 24.9MVA.

CitiPower has estimated the magnitude and impact of loss of load by considering the energy at risk and the annual hours at risk. These estimates, exclude any planned augmentation or operational response such as load transfers to mitigate the impact of an outage.

For example in 2026, CitiPower estimates there will be 8 MVA of load at risk and for 27 hours it would not be able to supply all customers from the zone substation if there is a failure of one of the transformers at RD. That is, it would not be able to supply all customers during high load periods following the loss of a transformer.

To address the anticipated system constraint at the RD zone substation, CitiPower considers that the following network solutions could be implemented to manage the load at risk:

- contingency plan to transfer load away via 11kV links to adjacent zone substations of Burwood (**BW**), Deepdene (**L**), Gardiner (**K**) and Camberwell (**CL**) up to a maximum transfer capacity of 8.7 MVA
- establish a third transformer at RD at cost of \$3.6 million

CitiPower's preferred option is to establish a third transformer at RD. However given that the forecast annual hours at risk is low, this project is not expected to occur during the forecast period. Although the expected demand will exceed the station's N-1 cyclic rating, the use of contingency load transfers will mitigate some of the risk in the interim period.

7.2.6 West Brunswick (WB) zone substation

The zone substation in West Brunswick (**WB**) is served by sub-transmission lines from the West Melbourne terminal station (**WMTS**). This station supplies the domestic, commercial and industrial areas of Brunswick West.

Currently, the WB zone substation is comprised of two 20/30MVA transformers operating at 66/6.6kV. The maximum demand is forecast to be 36.9 MVA in summer 2021/22 which will exceed the N-1 cyclic capacity of 17.1MVA.

For the historical and forecast asset ratings and forecast station maximum demand, please refer to the System Limitations Template.

CitiPower estimates that in 2026 there will be 18.9 MVA of load at risk and 3584 hours of the year it would not be able to supply all customers from the zone substation if there is a failure of one of the transformers at WB. That is, it would not be able to supply all customers during high load periods following the loss of a transformer.

To address the anticipated system constraint at WB zone substation, CitiPower considers that the following network solutions could be implemented to manage the load at risk:

- install a new 20/30MVA third transformer at WB zone substation with third bus, offload C ZS to WB ZS at 6.6kV for an estimated cost of \$18.7 million. Rebuild of C ZS is then avoided and the site will be available for a rebuild once offloaded
- augment WB ZS and distribution feeders to 11kV system for an estimated extra cost of \$4 million.

CitiPower's preferred option is to install a new 20/30MVA third transformer at WB zone substation with third bus, offload C ZS to WB ZS at 6.6kV and decommission existing aged and poor condition assets at C ZS in 2022. Please refer to the System Limitations Template for further information regarding the preferred network investment.

7.3 Proposed new zone substations

This section sets out CitiPower's plans for new zone substations. These substations are not taken into account in the forecasts that have been referred to in the Forecast Load Sheet or in the analysis in section 7.1 above which relates to existing substations.

In summary, CitiPower has committed to building the zone substation set out below in Table 7.2 during the forward planning period.

Table 7.2 Proposed new or redeveloped zone substations

Name	Location	Proposed commissioning date	Reason
Tavistock Place (TP)	Melbourne CBD	Nov 2025	Achieve CBD Security of Supply project objectives

Greater detail on the new zone substation is provided in subsections below.

In addition to the new zone substation noted in the table above, CitiPower is also in discussions with the State Government of Victoria and local councils relating to new developments and the demand for new electricity services in areas including:

- Fishermans Bend precinct: Places Victoria has released its updated strategic framework for the redevelopment of this area to provide homes for more than 80,000 residents and new workplaces for up to 60,000 people. This urban renewal will involve a variety of residential and commercial developments ranging from townhouses to high rise towers and small to large commercial spaces⁷. This may result in a requirement for an additional 30MVA of capacity

⁷ Refer: <https://www.development.vic.gov.au/projects/fishermans-bend>

-
- Arden Macaulay: the City of Melbourne has identified the 147 hectare precinct in parts of Kensington and North Melbourne as an urban renewal area that will accommodate significantly more residents and employment growth over the next 30 years.

These loads are not yet included in the demand forecasts in the Forecast Load Sheet. These developments are likely to result in significant augmentation to the CitiPower network, including the possible construction of new zone substations.

7.3.1 Tavistock Place (TP) zone substation

CitiPower is planning to rebuild the existing zone substation at Tavistock Place (**TP**), located in the South West district of the Melbourne CBD. It will be upgraded from the existing 22/6.6kV to 66/11kV with higher capacity.

Elements of the new zone substation are required as part of the Melbourne CBD security program which seeks to increase resilience into the 66kV sub-transmission network given the critical nature of reliable electricity supply to the area. The CBD security work associated with TP involves providing extra capacity at 11kV to allow the offloading of LQ and JA zone substations, consistent with the CBD Security of Supply project objectives.

The TP zone substation will take load from the following adjacent zone substations:

- Little Bourke (**JA**): 14 MVA
- Little Queen (**LQ**): 24 MVA.

Other benefits of the new zone substation are to support load growth in Southbank and Docklands and defer major augmentations at the heavily loaded JA, LQ and Southbank (SB) zone substations. Without completing the works at TP, there will be a shortage of circuit breakers in the western CBD, which will prevent the connection of further large loads, such as high rise buildings.

Completing the works at TP will introduce additional circuit breakers into the western CBD and Docklands area. It is currently forecast that no spare circuit breakers will be available in any of the western CBD and Docklands zone substations by the end of 2023. Without circuit breakers it will no longer be possible to connect any new large loads such as high rise buildings.

The planned commissioning date for the TP zone substation was to be November 2023, with feeder offload works completed by end of 2024, at an estimated total cost of \$24.5 million (including the cost of the sub-transmission lines). During the covid lockdowns, CitiPower has observed a reduction in the peak demand of Melbourne CBD network due to shutdown of retail businesses and restricted access to offices. As a result, the risk of 'N-1 Secure' was lower than previously forecasted. Currently the TP rebuild project is being reviewed and the timing is yet to be confirmed.

Solutions are being prepared which meet the aims of the CBD Security of Supply project, which shall be assessed via the RIT-D process.

8 Sub-transmission Lines Review

This chapter reviews the sub-transmission lines where further investigation into the balance between capacity and demand over the next five years is warranted, taking into account the:

- forecasts for N-1 maximum demand to 2026
- line ratings for each sub-transmission line.

Where the sub-transmission line is forecast to operate with maximum demands greater than 5 per cent above their summer or winter rating, under N-1 conditions during 2021, this chapter assesses the energy at risk for those assets. Solutions may also address zone substation constraints at the same time.

If the energy at risk assessment is material, then CitiPower sets out possible options to address the system limitations. CitiPower may employ the use of contingency load transfers to mitigate the system limitations although this will not always address the entire load at risk at times of maximum demand. At other times of lower load the available transfers may be greater. As a result, the use of load transfers under contingency situations may imply a short interruption of supply for customers to protect network elements from damage and enable all available load transfers to take place.

Non-network providers may wish to review the limitations and consider whether alternative solutions to those set out in the analysis may be suitable. The annualised cost of the preferred network option provides a broad indication of the maximum potential value available to proponents of non-network solutions in deferring or avoiding network augmentation. However, it should be noted that the value of a non-network solution depends on the extent to which it defers or avoids a network augmentation, and the expected timing of the network augmentation. Non-network proponents are encouraged to discuss opportunities to provide alternatives to the network options presented in this chapter.

CitiPower notes that all other sub-transmission lines that are not specifically mentioned below either have loadings below the relevant rating or the loading above the relevant rating is minimal and can be addressed using the load transfer capability. In these cases, all customers can be supplied following the failure or outage of an individual network element.

Finally, sub-transmission lines that are proposed to be commissioned during the forward planning period are also discussed.

8.1 Sub-transmission lines with forecast system limitations overview

Using the analysis undertaken below in section 8.2, CitiPower proposes to augment the sub-transmission lines listed in the table below to address system limitations during the forward planning period.

Table 8.1 Proposed sub-transmission line augmentations

Sub-transmission line	Description	Direct cost estimate (\$ million)				
		2022	2023	2024	2025	2026
FBTS-TP-SB*	Establish 2 new 66kV lines to rebuilt TP and reconfigure at sub-transmission exits at SB				7	
JA-TP-WP*	Cut into existing JA-WP cable and run in and out of rebuilt TP				3.5	

* NB solution for CBD Security of Supply is under review, considering most recent forecast data accounting for the effect of the COVID-19 pandemic on the CBD. At this stage the baseline solution for TP Zone Substation is retained whilst alternatives are developed.

The excel based detailed system limitation reports for the subtransmission lines with forecast limitations can be found at the link below by searching for sub transmission system limitation report:

<https://spaces.hightail.com/space/UaPnYI6yeV>

The options and analysis is undertaken below.

8.2 Sub-transmission lines with forecast system limitations

CitiPower does not propose to augment any sub-transmission lines to address system limitations in the next 5 years.

8.2.1 BTS-F179 22 kV sub-transmission line

The BTS-F179 22 kV sub-transmission line supplies the Fitzroy (F) zone substation from Brunswick terminal station (BTS) at 22 kV.

For the historical and forecast asset ratings and forecast station maximum demand, please refer to the System Limitations Template.

CitiPower estimates that in 2026 for the lines within this loop there will be:

-
- 3.0 MVA of load at risk, and for 194 hours it will be unable to supply all customers on the BTS-F179 line during an outage of the BTS-F189 line.

To address the anticipated system constraints within this sub-transmission loop, CitiPower considers that the following network solutions could be implemented to manage the load at risk:

- Contingency plan to transfer load away via 6.6kV links to adjacent zone substation of Brunswick (C) up to a maximum transfer capacity of 4.6 MVA for 2021/22 summer, however these load transfers will become unavailable as zone substation C is to be offloaded and retired by end of 2022.
- Offload F to CW and convert the 6.6kV feeders to 11kV to enable more transfers for an estimated cost of \$15.0 million.

CitiPower's preferred option is to offload F and convert the 6.6kV feeders to 11kV by end of 2026 to meet the load growth in Fitzroy and Collingwood area as well as to reduce the load at risk for an N-1 event.

8.2.2 BTS-F189 22 kV sub-transmission line

The BTS-F189 22 kV sub-transmission line supplies the Fitzroy (**F**) zone substation from Brunswick terminal station (**BTS**) at 22 kV.

For the historical and forecast asset ratings and forecast station maximum demand, please refer to the System Limitations Template.

CitiPower estimates that in 2026 for the lines within this loop there will be:

- 1.0 MVA of load at risk, and for 14 hours it will be unable to supply all customers on the BTS-F189 line during an outage of the BTS-F179 line.

To address the anticipated system constraints within this sub-transmission loop, CitiPower considers that the following network solutions could be implemented to manage the load at risk:

- Contingency plan to transfer load away via 6.6kV links to adjacent zone substation of Brunswick (C) up to a maximum transfer capacity of 4.6 MVA for 2021/22 summer, however these load transfers will become unavailable as zone substation C is to be offloaded and retired by end of 2022.
- Offload F to CW and convert the 6.6kV feeders to 11kV to enable more transfers for an estimated cost of \$15.0 million.

CitiPower's preferred option is to offload F and convert the 6.6kV feeders to 11kV by end of 2026 to meet the load growth in Fitzroy and Collingwood area as well as to reduce the load at risk for an N-1 event.

8.2.3 TSTS-L 66 kV sub-transmission line

The TSTS-L sub-transmission line supplies the Deepdene (**L**) zone substation from Templestowe terminal station (**TSTS**) at 66 kV.

For the historical and forecast asset ratings and forecast station maximum demand, please refer to the System Limitations Template.

CitiPower estimates that in 2023 for the lines within this loop there will be:

- 1.2 MVA of load at risk, and for 1 hour it will be unable to supply all customers on the TSTS-L line during an outage of the TSTS-HB line.

To address the anticipated system constraints within this sub-transmission loop, CitiPower considers that the following network solutions could be implemented to manage the load at risk:

- Contingency plan to transfer load away via 11kV links to adjacent zone substations of Camberwell (CL), North Richmond (NR) and Riversdale (RD) for up to a maximum transfer capacity of 14.4 MVA.

CitiPower's preferred option utilise the 11kV feeder ties to reduce the load at risk for an N-1 event on the TSTS-L-Q-HB sub-transmission loop.

8.3 Proposed new sub-transmission lines

This section sets out CitiPower's plans for new sub-transmission lines. These lines are taken into account in the forecasts that have been set out in the Forecast Load Sheet and the analysis in section 8.2 above which relates to existing sub-transmission lines.

In summary, CitiPower has committed to building the sub-transmission lines set out below in table 8.2 during the forward planning period.

Table 8.2 Proposed new sub-transmission lines

Name	Location	Proposed commissioning date	Reason
JA-TP-WP*	TP cut in existing JA-WP cable	Nov 2025	CBD security requirements
FBTS-TP, TP-SB*	Fishermans Bend to CBD to South Melbourne	Nov 2025	CBD Load requirements while complying with CBD Security

* NB solution for CBD Security of Supply is under review, considering most recent forecast data accounting for the effect of the COVID-19 pandemic on the CBD. At this stage the baseline solution for TP Zone Substation is retained whilst alternatives are developed.

Each of these lines is described in more detail below.

8.3.1 JA-TP-WP

To meet the CBD security requirements, a second source of 66kV supply is to be established for the new TP zone substation. CitiPower plans to extend JA-WP cable to TP so as to enable supply from WMTS for TP at an estimated cost of \$3.5 million.

8.3.2 FBTS-TP, TP-SB

CitiPower plans to build a new zone substation at TP once the existing substation is demolished. It will be supplied at 66kV from FBTS and complete the loop via SB at an estimated cost of \$7 million.

9 Primary Distribution Feeder Reviews

This chapter reviews the primary distribution feeders where further investigation into the balance between capacity and demand over the next two years is warranted, taking into account the:

- forecasts for maximum demand to 2023
- summer and winter cyclic ratings for each feeder.

Where the feeders are forecast to operate with maximum demands at their firm summer or winter rating over the next two years, then this section assesses the energy at risk for those assets.

This review considers the primary section of a feeder, or what is commonly known as the backbone of the feeder exiting the zone substation to the first point of load for a customer.

If the energy at risk assessment is material, then CitiPower sets out possible options to address the system limitations. CitiPower may employ the use of contingency load transfers to mitigate the system limitations although this will not always address the entire load at risk at times of maximum demand. At other times of lower load the available transfers may be greater. As a result, the use of load transfers under contingency situations may imply a short interruption of supply for customers to protect network elements from damage and enable all available load transfers to take place.

Non-network providers may wish to review the limitations and consider whether alternative solutions to those set out in the analysis may be suitable. Solutions may also address distribution feeder constraints at the same time.

Finally, distribution feeders that are proposed to be commissioned during the next two years are also discussed.

9.1 Primary distribution feeders with forecast system limitations overview

Using the analysis undertaken below in section 9.2, CitiPower proposes no distribution feeder augmentations in the next two years.

9.2 Proposed new primary distribution feeders

The following primary distribution feeder projects are currently sitting outside of the primary feeder forecast period. It is however proposed to commence scope investigation and option analysis in 2022-23.

Table 9.2 Future primary distribution feeder projects

CL new 11kV feeder	RD new 11kV feeder
L new 11kV feeder	B new 11kV feeder
NR new jumbo feeder	L010 augmentation of U/G cable

10 Joint Planning

This chapter sets out the joint planning with DNSPs and TNSPs in relation to zone substations and sub-transmission lines. Joint planning in relation to terminal stations in isolation is discussed in the Transmission Connection Planning Report.

CitiPower has not identified any new required projects from our joint planning activities with other DNSPs in 2021. Our joint planning activities have included sharing load forecast information and load flow analysis between Victorian distributors relating to the sub-transmission system. Where a constraint is identified on our network that may impact another distributor, then project specific joint planning meetings are held to determine the most efficient and effective investment strategy to address the system constraint.

10.1 West Melbourne terminal station 22kV sub-transmission

CitiPower and AusNet Services continue to jointly plan options for the replacement of the 220/22kV assets at West Melbourne terminal station (**WMTS**). During 2015 a study assessed the overall costs, including both distribution and transmission costs, depending on whether:

- Option 1: the assets are replaced on a like-for-like basis or
- Option 2: the WMTS 22 assets are not replaced and CitiPower transfers all load from the 22kV sub-transmission network to the 66kV network.

The joint analysis shows that the least cost alternative to replacing the 220/22kV assets at WMTS is to retire the WMTS 220/22kV and CitiPower 22kV sub-transmission assets, replace the minimum ageing CitiPower assets and transfer the majority of the 22/6.6kV load to the 66/11kV network.

Further details of the retirement and transfer works required are discussed below in section 14.1.16.

11 Changes to Analysis Since 2020

The following information details load forecasts and project timing changes that have occurred since the publication of the 2020 DAPR.

11.1 Constraints addressed or reduced due to projects completed

CitiPower has undertaken the following projects in 2021 to address constraints which were identified in the 2020 DAPR:

- **RP** zone substation feeders have been converted to 11kV and supplied from WP
- RTS-RP125 sub transmission line rating has been de-commissioned

11.2 New constraints identified

Changes in load forecasts or other factors during 2021 have resulted in CitiPower undertaking risk assessments for the zone substations and sub-transmission loops which were not included in the 2020 DAPR:

- **(E)** capacity has reduced resulting in load at risk.

11.3 Other material changes

In addition to the matters identified above, material changes compared to the 2020 DAPR include:

- **(BQ)** load forecasts have reduced resulting in no load or hours at risk above threshold limits
- **(B)** load forecasts have reduced resulting in no load or hours at risk above threshold limits

12 Asset Management

This chapter provides information on the CitiPower asset management approach including the strategy employed, impacts on system limitations and where further details can be obtained.

12.1 Asset Management Framework

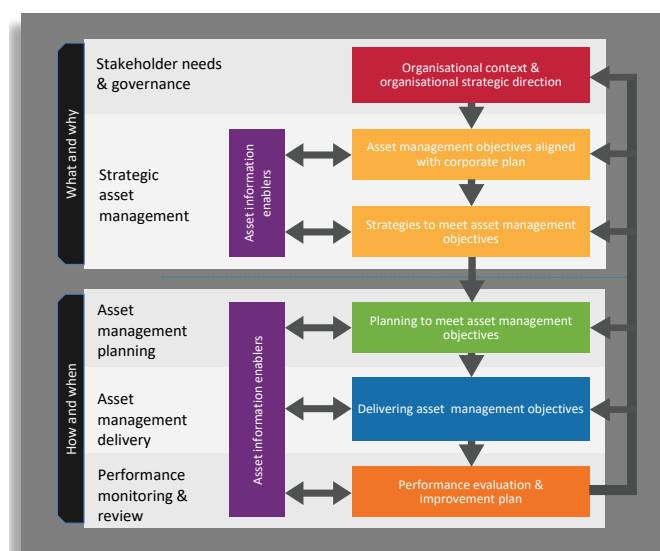
CitiPower are committed to the application of best practice asset management strategies to ensure the safe and reliable operation of our electrical network. CitiPower is continuing to develop and implement an asset management system that is aligned with the requirements of ISO 55001:2014, the international standard in asset management.

The Asset Management System (**AMS**) Framework is a high-level document that describes the asset management system that CitiPower applies to its network assets. The AMS Framework identifies CitiPower's asset management roles and accountabilities, and all significant steps and processes involved in the asset life cycle from the identification of need to creation, operation, maintenance and eventual disposal. Our AMS consists of five key levels:

- Level 1: Stakeholder needs and governance
- Level 2: Strategic Asset Management
- Level 3: Asset management planning
- Level 4: Asset management delivery
- Level 5: Performance monitoring and review

The structure and hierarchy of the AMS is illustrated in Figure 12.1.

Figure 12.1 Asset Management System Framework



Levels 1 and 2 describe 'What' asset management strategies and objectives are to be targeted and provide details regarding 'Why' these are required. Level 3 describes the approach taken to plan and budget for the delivery of the asset management activities, while level 4 describes 'how' and 'when' these activities are delivered to meet the strategies and objectives. Level 5 describes CitiPower's approach to performance monitoring and review of the asset management system.

The relationships between CitiPower's strategic asset management documentation are shown in figure 12.2. These strategic documents describe what asset management strategies and objectives are to be targeted and provide details regarding why these are required.

Figure 12.2 Strategy and planning document hierarchy



An overview of these documents is provided in the following sections.

12.1.1 Strategic Asset Management

CitiPower's asset management strategies and objectives are aligned to the asset management policy and to the needs of our stakeholders, including the direction articulated in our organisational strategic pillars and the asset management-related commitments made in our approved regulatory submission.

The strategic asset management level of CitiPower's AMS framework comprises the following key components:

- asset management objectives
- asset management policy
- Strategic Asset Management Plan (SAMP)
- asset management strategies
- asset class strategies

12.1.1.1 Asset Management Objectives

CitiPower's asset management objectives form the basis for evaluating the success of the asset management system in delivering against the organisational strategic pillars.

The asset management objectives for CitiPower are:

- manage and operate the network safely
- meet our network reliability performance targets
- manage our assets on a total life cycle basis at least cost
- adapt to our customer's future needs
- manage our compliance obligations
- empower and invest in our employees
- monitor opportunities and drive continuous improvement

The AMS Framework maps the asset management policy principles and asset management objectives to demonstrate the alignment to the organisational strategic pillars.

12.1.1.2 Asset Management Policy

CitiPower's Asset Management **(AM)** Policy drives all asset management activities in our organisation. The AM Policy is a high-level statement providing:

- Our overall approach to asset management;
- The principles to be followed, and direction for establishing asset management strategies and objectives; and
- Management expectations regarding asset management outcomes.

The AM Policy requires asset management activities to meet business objectives and benefit the current and future needs of all customers, stakeholders and employees.

12.1.1.3 Strategic Asset Management Plan

CitiPower's strategic asset management plan **(SAMP)** identifies our high-level strategies and objectives for asset management, and links these to CitiPower's 'five strategic pillars', providing line of sight to the organisational strategy. The SAMP takes full account of our approaches to network risk and asset investment decision making, and provides long-term guidance for the development of the asset management strategies and class strategies.

12.1.1.4 Asset Management Strategies

Asset management strategies have been developed for eight subject areas to deliver CitiPower's SAMP objectives. The Asset Management Strategy subjects are not asset specific and apply across all asset classes. Individual subject strategies are developed by considering:

- CitiPower's organisational context and key asset management issues of a range of internal stakeholders
- the asset management requirements of a range of external stakeholders, including the AER, AEMO and CFA.

The asset management strategies provide guidance for development of asset operational plans and asset management plans, to prioritise and deliver the asset management objectives and strategies. Refer to appendix D for a detailed list of the asset management strategy subjects and purpose of each strategy.

12.1.1.5 Asset Class Strategies

CitiPower has identified sixteen asset class strategies (**ACS**) for which specific strategies and objectives have been developed, all of which are aligned to the SAMP. Each ACS is formed from analysis of the required performance in terms of reliability and quality of supply, risk profile, functionality, availability and safety. The ACSs provide guidance for development of asset operational plans and asset management plans, which drive inspection, maintenance, condition monitoring, maintenance policies and work instructions. Refer appendix D for a detailed list of ACS documents and corresponding asset coverage.

12.1.2 Asset Management Planning

CitiPower plans its asset management activities to maximise the value realised over the life of its assets. The asset management planning stream of CitiPower's AM Framework is undergoing further development, with key focusses on asset investment planning, asset maintenance requirements and optimising the asset lifecycle.

CitiPower has implemented a new value framework that will form the basis for quantitatively prioritising investments. The value framework is used to configure the Copperleaf C55 asset planning and investment tool to facilitate the quantitative prioritisation of investments going forward.

12.1.3 Asset management delivery

CitiPower's asset management delivery and governance is facilitated via existing standards, policy, procedures and processes that stipulate the requirements for our asset management delivery. Monitoring of compliance is achieved via regular internal audit processes and reporting. CitiPower's asset management committee provides specific oversight and governance to the Asset Management System.

12.1.4 Performance monitoring and review

CitiPower monitors the performance of both network assets and the asset management system as a whole. The components of CitiPower's performance monitoring and review level of the AM framework are outlined below:

- risk assessment and management
- business continuity planning
- change management
- asset performance and health monitoring
- asset management monitoring and continual improvement
- audit and assurance

-
- stakeholder engagement

Considerable capital investment has been made to configure the network to provide real-time asset performance data that is used to develop a range of high and lower level performance indicators, including those that are required to be reported under the terms of our distribution licence. Additionally, CitiPower conducts a range of internal and external reviews of the network and asset management system performance through internal audits, external audits and via regular management reviews. Where improvements to the AMS are required, these are consolidated into an AMS improvement plan.

12.1.5 Impact of Asset Management on System Limitations

Electrical plant and conductor ratings may be affected by asset management activities in that a condition assessment could result in a higher or lower operating temperature. This could improve ratings to defer augmentation costs or lower ratings which will tend to bring forward expenditure whilst maximising system reliability, safety and security of supply. In addition, chapters 3 and 14 of this DAPR cover the effect on the system of ageing and potentially unreliable assets.

12.1.6 Distribution Losses

Distribution losses refer to the energy used in transporting it across distribution networks. In 2019/20, 4.2 per cent of the total energy into the CitiPower network was made up of losses. This is essentially calculated as the difference between the energy that CitiPower procures and that which it supplies. These losses represent 88 per cent of CitiPower's total greenhouse gas emissions, as defined under the *National Greenhouse and Energy Report Act*.

CitiPower has a process to identify, justify and implement augmentation plans to address network constraints. Whilst loss reduction alone is not the main contributing factor in the decision of the preferred option, it is seen as the deciding factor if all other factors are equal. CitiPower, as part of its plant selection process takes into account the cost of losses in its evaluation for transformer purchases.

12.1.7 Contact for further information

Further information on CitiPower's asset management strategy and methodology can be obtained from contacting CitiPower Customer Service:

- General Enquiries 13 22 06
- Website www.CitiPower.com.au

Detailed enquiries may be forwarded to the appropriate representatives within CitiPower.

13 Asset Management Methodologies

The Asset Management Framework (AMF) describes the Asset Management System (AMS) that is applied to CitiPower's network assets, and requires the AMS to:

- support the asset life cycle
- recognise the value of assets in decision-making at each stage of the life cycle
- enable asset management decisions to be optimised based on quantified risk, asset performance and life cycle cost.⁸

CitiPower's assets are subject to relevant condition assessment methods through planned inspection, monitoring and maintenance programs. These programs have been developed taking into account regulatory obligations, industry knowledge as well as proven and established asset management methodologies.

CitiPower's preferred asset management methodologies⁹ applied to its network assets are as follows:

- Reliability-Centred Maintenance (RCM) — CitiPower applies a reliability and safety-based regime which is based on the principles of RCM methodology together with regulatory obligations and risk assessment that are built into the asset management procedures. It is applied to routine replacement expenditure for high-volume assets such as poles, pole top-equipment, cross-arms, insulators, etc. The approach has regard for the asset age, condition and operating environment
- Condition Based Risk Management (CBRM) — this methodology is applied to determine the condition of assets from routine inspection and maintenance, including the risk of the deterioration, of major items of plant and critical high volume asset replacements. These are discussed in more detail in the sections below.

⁸ CitiPower and Powercor Australia Asset Management System Framework (March 2019) page 7

⁹ Where the application of RCM or CBRM methodologies are not practical, alternative asset management methodologies are applied e.g high volume or low criticality asset classes

13.1 Reliability Centred Maintenance (RCM)

CitiPower applies a reliability and safety based regime, based on RCM principles, regulatory obligations and risk assessment, to high-volume assets such as poles, cross-arms, conductors etc.

The RCM process is used to determine what must be done to ensure that our physical network assets continue to operate at their intended performance levels at the most efficient cost. It is an internationally recognised and widely used methodology used to determine the most appropriate maintenance strategy for a particular class of asset at efficient cost.

For each asset type, the RCM process identifies possible ways in which a defect may occur in an asset, and the root cause of that defect. For each different type of defect, the possible impact on the safety, operations and other equipment in the network is assessed and a maintenance strategy is determined.

When implementing the RCM methodology for the inspection of assets, the risks associated with asset failures have been considered together with the inspection and repair costs to determine the most efficient inspection frequency and timeframe for repair of identified defects. Where a defect is identified, the maintenance strategy to address that defect is implemented. This may involve either asset replacement or maintenance measures to prolong the asset's life, such as pole staking. Asset replacements for Poles assets are not determined by RCM alone, the RCM is an input into the CBRM model which provides a more granular quantification of risk and appropriate interventions.

The RCM process can be summarised by a series of steps, as follows.

Figure 13.1 Steps in the RCM process to develop a maintenance strategy

1. Select functions and performance standard of asset	• ensure the asset continues to do what its users want it to do • consider primary functions and secondary functions of asset
2. Identify function failures	• identify the ways in which the asset may fail to fulfil its functions
3. What causes each functional failure	• identify all of the events which are reasonably likely to cause each failed state • includes failures which have occurred on the same or similar equipment; are prevented by existing maintenance procedures; and those which possibly may occur
4. What happens when failure occurs	• list all failure effects that describe what happens when a failure mode occurs, including supporting evidence • e.g. what is the evidence that a failure has occurred, how does it pose a threat to safety or the environment
5. How does the failure matter	• consequences of failure of a hidden function, where failure will not become evident to operators under normal circumstances • consequence of failure of an evident function in terms of the impact on safety, environment, operational and non-operational matters
6. How to prevent or predict each failure	• identify the most appropriate maintenance strategy for each failure mode, which is also technically and economically feasible • where it is not possible to identify a pro-active task, select default actions such as proof testing, re-design or run to failure
7. Regularly review process	• once maintenance recommendations are put into practice, these are routinely reviewed and renewed as additional information is found

RCM analysis is undertaken by taking into account the equipment manufacturer's recommendations, the physical and electrical environment in which the asset is installed, fault and performance data, test data, condition data, regulations, duty cycles as well as many years of field-based experience.

The combination of general maintenance requirements and the specific requirements based on the environments in which the assets operate, may result in varying maintenance and condition monitoring regimes for the same type of asset. Tests and inspections are undertaken using tools such as thermal imagery, visual inspections, and invasive pole testing to assess asset condition.

The following example demonstrates how we apply RCM methodology in the case of wood poles, in practice:

1. Data collection — population demographics are determined so that the volume, age, strength, location and timber species is known. Each of these parameters are analysed to determine how they impact on the performance of poles and may require differing

maintenance strategies. Performance data is gathered to determine defect rates, population condition, failure rates and root causes of failures.

2. RCM analysis team — a team of subject matter experts are assembled comprising employees and industry representatives (wood pole suppliers, other authorities, research bodies) to undertake the analysis.
3. Failure mode analysis — all the known and potential failure modes are identified. This generally includes identification of the following:
 - function of the asset
 - failure types
 - potential impacts of failure
 - potential causes of failure.
4. Maintenance policy developed — appropriate maintenance policies are determined for each failure mode to meet the required performance. This performance is generally expressed as an availability rate for the asset. The maintenance strategies include inspection frequencies, pole treatment frequencies (fungal decay), pole reinstatement, redesign, pole replacement and termite treatment.
5. Systems updated — the policy development/RCM process determines the frequency of inspections based on risk and economics. SAP (our corporate asset management system) then applies the policy rules to the poles to ensure that inspections take place with the right frequency based on that prioritisation. Prioritised inspections are automatically generated and notifications are created to undertake any required maintenance actions triggered during the inspection process.
6. Monitoring — performance of maintenance strategies are monitored such as defect and failure rates to ensure effective implementation and verification of expected outcomes. A further review may be undertaken should performance not meet expectation.

Maintenance and associated condition monitoring policies are reviewed periodically. When new assets are introduced into the network, existing maintenance and condition monitoring plans are reviewed to ensure coverage of the change or new plans are created as appropriate.

Maintenance plans, policies, tasks and work instructions are captured and managed in the SAP Maintenance Management system. The RCM rules are configured in SAP, which automatically generates time based work orders for inspection and maintenance planning.

As part of the Pole Management Improvement Program, a pole CBRM model is being established for implementation mid-2021 to enable a risk based asset management approach. This will result in proactive pole interventions on a risk justified basis when operationalised.

A.1. Location and timing of asset retirements

The location and the timing of the retirements of high volume asset types is not available at the start of any planning year. The location of the asset is determined only once an

inspection is carried out and if a defect is detected. The severity of the inspected defect will determine the maximum time that can lapse before action is taken.

13.2 Condition Based Risk Management (CBRM)

CBRM is a structured methodology that combines CitiPower's engineering experience, asset information, environmental factors, operating context to define current and future condition, performance and to quantify consequence and risk of asset failure for network assets.

The CBRM methodology that CitiPower uses has been developed by EA Technology and is integrated into CitiPower's asset and investment planning software¹⁰.

CitiPower applies the CBRM methodology to the following asset classes:

- poles
- zone substation transformers and regulators
- zone substation and switching station switchboards
- zone substation and switching station circuit breakers
- protection relays
- low voltage circuit breakers
- ring main units.

Where applicable, new asset models are developed and implemented by CitiPower to quantify and manage asset risk through prioritised interventions. The following models are currently under development:

- high voltage distribution cables
- distribution regulators.

The CBRM process can be summarised by a series of sequential steps, which is set out below.

¹⁰ Copperleaf Investment Planning and Management software

Table 13.1 Steps in the CBRM process

Step	Description
1	Define asset condition Health indices (HI) are derived for individual assets within different asset groups. Health indices are described on a scale of 0 to 10, where 0 indicates the best condition and 10 the worst.
2	Link current condition to performance Health indices are calibrated against relative probability of failure (PoF). The HI/PoF relationship for an asset group is determined by matching the HI profile with the relevant observed failure rates.
3	Estimate future condition and performance Knowledge of degradation processes is used to trend health indices over time. This ageing rate for an individual asset is dependent on its initial HI and operating conditions. Future failure rates can then be calculated from aged HI profiles and the previously defined HI/PoF relationship.
4	Evaluation of potential interventions in terms of PoF and failure rates The effect of potential replacement, refurbishment or changes to maintenance regimes can then be modelled and the future HI profiles and failure rates reviewed accordingly.
5	Define and weight consequences of failure (CoF) A consistent framework is defined and populated in order to evaluate consequences in significant categories such as network performance, safety, financial, environmental, etc. The consequence categories are weighted to relate them to a common unit.
6	Build risk model For an individual asset, its probability and consequence of failure are combined to calculate risk. The total risk associated with an asset group is then obtained by summing the risk of the individual assets.
7	Evaluate potential interventions in terms of risk The effect of potential replacement, refurbishment or changes to maintenance regimes can then be modelled to quantify the potential risk profile associated with different strategies.
8	Review and refine information and process Building and managing a risk based process driven by asset specific information is not a one-off process. The initial application will deliver results based on available information and crucially, identify opportunities for ongoing improvement that can be used to build an improved asset information framework.

In terms of the steps in the process:

- steps 1 to 4 essentially relate to condition and performance and provide a systematic process to identify and predict end-of-life. Future investment plans can then be linked to probability of failure and failure rates
- steps 5 to 7 deal with consequence of failure and asset criticality that are combined with PoF values to enable definition and quantification of risk
- step 8 is a recognition that building and operating a risk-based process using asset specific information is not a one-off exercise.

Each year, CitiPower updates the data in its CBRM models as part of its budget submission process. CitiPower reviews the outputs of the CBRM and identifies the projects that deliver the greatest risk reduction. The latter projects are determined by calculating the difference between the risk in a future year if the asset is not replaced and the risk that would result if the plant is replaced, and then assessing the various options to deliver the risk reduction.

While the CBRM methodology identifies a proposed year for the replacement of an asset, timing of the investment may change due to:

- risk reduction benefits of the project when compared to other projects
- alignment opportunities with augmentation projects for delivery synergies.

13.3 Other methodologies

Condition-based monitoring and risk-based economic assessment is not possible or cost-effective for all types of plant and equipment. Some plant and equipment rely upon inspection cycles, similar to poles and wires, while others rely on age as the best estimate of condition. Some assets that do not directly impact the performance of the network, and for which the cost of implementing a condition-based or a risk-based approach outweighs the benefit, are run to failure. Other assets, such as surge arrestors, are designed to only be used once and are replaced upon use.

Details of retirement and replacement methodologies for these assets are set out in the relevant asset management plans, and explained in the next chapter.

14 Retirements and De-ratings

This chapter sets out the planned network retirements over the forward planning period. The reference to asset retirements includes asset replacements, as the old asset is retired and replaced with a new asset.

In addition, this chapter discusses planned asset de-ratings that would result in a network constraint or system limitation over the planning period.

The System Limitation Report details those asset retirements and de-ratings that result in a system limitation.

Where more than one asset of the same type is to be retired or de-rated in the same calendar year, and the capital cost to replace each asset is less than \$200,000, then the assets are reported together below.

14.1 Individual assets

A summary of the individual assets that are planned to be retired in the forecast planning period is provided in the table below. It indicates how the current retirement date has changed from the date specified in the 2020 DAPR. A more detailed assessment, including a consideration of non-network alternatives will be carried out at the business case and RIT-D stage. Further changes to the planned retirements and de-ratings below may arise from this further assessment.

Table.14.1 Planned asset retirements and de-ratings

Location	Asset	Project	Retirement date	2020 DAPR
Albert Park (AP) Zone Substation	AP 11kV No1 Bus - J18/J22 Circuit Breaker	Replacement	2025	2024
Albert Park (AP) Zone Substation	AP 11kV No2 Bus - J18/J22 Circuit Breaker	Replacement	2024	2024
Albert Park (AP) Zone Substation	AP 11kV No3 Bus - J18/J22 Circuit Breaker	Replacement	2024	2024

Location	Asset	Project	Retirement date	2020 DAPR
Celestial Avenue (WA) Zone Substation	Transformer 1	Replacement	2024	2022
Celestial Avenue (WA) Zone Substation	Transformer 2	Replacement	2026	2023
Collingwood (B) Zone Substation	B 11kV Email J18 HV Switchboard	Replacement	2024	2023
Fishermans Bend (FB) Zone Substation	FB 11kV No1 Bus - J18/J22 Circuit Breaker	Replacement	2025	2022
Fishermans Bend (FB) Zone Substation	FB 11kV No2 Bus - J18/J22 Circuit Breaker	Replacement	2025	2022
Fishermans Bend (FB) Zone Substation	FB 11kV No3 Bus - J18/J22 Circuit Breaker	Replacement	2025	2022
North Richmond (NR) Zone Substation	Transformer 2	Replacement	2026	2025
Toorak (TK) Zone Substation	TK 11kV No1 Bus - J18/J22 Circuit Breaker	Replacement	2026	2023
Toorak (TK) Zone Substation	TK 11kV No2 Bus - J18/J22 Circuit Breaker	Replacement	2026	2023

For the forward planning period there are no committed investments worth \$2 million or more to address urgent and unforeseen network issues.

The excel based detailed system limitation reports for asset replacements can be found at the link below by searching for asset replacement system limitation report:

<https://spaces.hightail.com/space/UaPnYI6yeV>

14.1.1 Albert Park (AP) Zone Substation 11kV No1, 2 & 3 Bus J18/J22 Circuit Breakers

The Albert Park (**AP**) zone substation is served by 66KV sub-transmission lines from the Fishermans Bend terminal station (**FBTS**) in a loop with Montague zone substations (**MG**). The three 20/27 MVA 66/11kV transformers feed three 11kV bus sections comprised of eleven 11kV feeders consisting of a mix of Email J18/J22 oil filled circuit breakers and Reyrolle LMVP vacuum circuit breakers. This project is to replace existing Email J18/J22 oil filled circuit breakers from bus section 1, 2 and 3.

The 11KV bus sections consists of old non arc fault contained Email J18 and J22 oil filled circuit breakers installed at transformer incomers, bus section ties and feeder positions which have been in service for 57 years.

The current CBRM model has determined that the J18 and J22 circuit breakers indicate a health index of 5.08 and projected health index of 5.76 in next five years, and is nonetheless forecast to replace No.1 Bus in 2025 and No. 2 and No. 3 Bus in 2024 respectively.

Currently this switchgear is inspected and tested according to twelve yearly maintenance plans. An oil filled J18 or J22 circuit breaker failure will risk the reliability of the network due to the inadequate spare parts availability and the unavailability of internal and external skilled resources to repair these old assets safely.

CitiPower estimates that with the 11kV J18 & J22 Circuit Breakers at AP Zone Substation retired at the end of their lifetime in 2026 there will be 51.2 MVA of load at risk and for 8760 hours it will be unable to supply all customers.

To address the anticipated constraints at AP zone substation switchboard, CitiPower considers that the following options could be implemented to manage the risk:

- replace Email J18 & J22 circuit breakers at AP zone substation with SF6 or Vacuum type new circuit breakers for an estimated cost of \$1.62 million
- Transfer load away to adjacent zone substations via 11kV links to adjacent zone substations of Montague (**MG**), St Kilda (**SK**) and South Melbourne (**SO**) up to a maximum transfer capacity of 6.4 MVA.

Given recent offline testing of the switchboard shows the insulation is in good condition, CitiPower's preferences is to replace the J18 & J22 circuit breakers within the existing switchboard.

14.1.2 Celestial Avenue (WA) Zone Substation Transformer 1

The Celestial Avenue (**WA**) zone substation is supplied at 66kV via sub transmission lines originating from West Melbourne terminal station (**WMTS**) and Brunswick terminal station (**BTS**) and currently comprises of two 66/11kV 20/27 MVA transformers and one 66/11kV 20/30 MVA transformer. WA zone substation supplies a portion of the central and eastern CBD in Melbourne.

CBRM analysis determined that the No.1 66/11kV 20/27 MVA transformer has a health index of 7.73 rising to 8.84 in next five year and that the associated risk can be efficiently mitigated by replacement in 2024. Retirement of the No.1 transformer would result in a significant shortfall of transformation capacity at WA zone substation. This would place the

customers supplied at risk of extended outages during times of unplanned network contingencies.

With No1 transformer retired, CitiPower estimates that in 2025 there will be 12.3 MVA of load at risk and for 391 hours in the year it will not be able to supply all customers from the zone substation if there is a failure of one of the two remaining transformers at WA. Also it would not be possible to maintain the CBD security standard.

To address the anticipated system constraint at WA zone substation, CitiPower considers that the following network solutions could be implemented to manage the risk:

- contingency plan to transfer load away via 11kV links to adjacent zone substations of Bouverie/Queensberry (**BQ**), and Victoria Market (**VM**) up to an estimated maximum transfer capacity of 12.2 MVA should a transformer fail in the interim
- replace the existing No1 transformer in 2024 with a new transformer of similar rating for an estimated cost of \$3.1 million.

CitiPower's preferred option is to replace the No.1 transformer in 2024. The use of contingency load transfers will mitigate the risk should the asset fail ahead of its forecast retirement date. For more details and data on the limitation please refer to the attached Systems Limitations Spreadsheet.

A demand side initiative to reduce the forecast maximum demand load by 12.3 MW at WA zone substation would defer the need for this capital investment by one year.

14.1.3 Celestial Avenue (WA) Zone Substation Transformer 2

The Celestial Avenue (**WA**) zone substation is supplied at 66kV via sub transmission lines originating from West Melbourne terminal station (**WMTS**) and Brunswick terminal station (**BTS**) and currently comprises of two 66/11kV 20/27 MVA transformers and one 66/11kV 20/30 MVA transformer. WA zone substation supplies a portion of the central and eastern CBD in Melbourne.

CBRM analysis determined that the No2 66/11kV 20/27 MVA transformer has a health index of 5.5 rising to 6.27 in 2026 and that the associated risk can be efficiently mitigated by replacement in 2026. Retirement of the No2 transformer would result in a significant shortfall of transformation capacity at WA zone substation. This would place the customers supplied at risk of extended outages during times of unplanned network contingencies.

With No2 transformer retired, CitiPower estimates that in 2027 there will be 15.2 MVA of load at risk and for 840 hours in the year it will not be able to supply all customers from the zone substation if there is a failure of one of the two remaining transformers at WA. Also it would not be possible to maintain the CBD security standard.

To address the anticipated system constraint at WA zone substation, CitiPower considers that the following network solutions could be implemented to manage the risk:

- contingency plan to transfer load away via 11kV links to adjacent zone substations of Bouverie/Queensberry (**BQ**), and Victoria Market (**VM**) up to an estimated maximum transfer capacity of 12.2 MVA should a transformer fail in the interim

- replace the existing No2 transformer in 2026 with a new transformer of similar rating for an estimated cost of \$3.1 million.

CitiPower's preferred option is to replace the No2 transformer in 2026. The use of contingency load transfers will mitigate the risk should the asset fail ahead of its forecast retirement date. For more details and data on the limitation please refer to the attached Systems Limitations Spreadsheet.

A demand side initiative to reduce the forecast maximum demand load by 15.2 MW at WA zone substation would defer the need for this capital investment by one year.

14.1.4 Collingwood (B) Zone Substation 11kV Email J18 HV Switchboard

The Collingwood (B) zone substation is served by two sub-transmission lines from the Richmond terminal station (RTS) in a loop with North Richmond (NR) and Collingwood (CW) zone substations. This zone substation supplies the Collingwood and Fitzroy areas.

Currently, B zone substation is comprised of two 20/27 MVA transformers operating at 66/11kV and connected to 66kV sub-transmission lines from CW and NR.

The insulation on the 11kV switchboard has been compromised due to a CB failure in 2016 and cannot be reconditioned. Whilst fit for service, these repairs are not a long term solution as evident from the intermittent low level PD (**partial discharge**) detected from the online monitoring system, and is nonetheless forecast to require replacement in 2024.

The B zone substation consists of 4 air insulated bus sections with twenty five J18 and J22 oil circuit breakers.

This switchgear has been in service since 1965 and the CBRM model has determined a health index of the Email CBs rising to 4.71 in the next five years. The average health index of the switchboard is rising to 5.36 in the next 5 years.

According to the zone substation switchgear asset class strategy, CitiPower plans to reduce the population of non arc fault contained switchboard with oil filled old circuit breakers to significantly reduce the fire risks and network reliability risks should a catastrophic failure occurred of these oil filled circuit breakers.

This switchgear is currently inspected and tested according to twelve yearly maintenance plans. In addition, the online PD monitoring sensors has been installed on this switchboard for continuous monitoring. This ensures early detection of the potential failures and taking control measures in event of a failure prior to the complete replacement in 2024.

CitiPower estimates that with the 11kV switchboard retired at the end of its lifetime in 2024, the entire zone substation load of 31.4 MVA will be at risk and for 8760 hours in the year it will not be able to supply any customers from the zone substation.

To address the anticipated system constraint at B zone substation, CitiPower considers that the following network solutions could be implemented to manage the risk:

- contingency plan to transfer load away via 11kV links to adjacent zone substations of Collingwood (CW) and North Richmond (NR) up to a maximum transfer capacity of 9.5 MVA should a circuit breaker fail in the interim

- replace 11kV switchboard at B in 2023 for an estimated cost of \$8.3 million.

CitiPower's preferred option is to replace the 11kV switchboard in 2024. The use of contingency load transfers will mitigate the risk should the asset fail ahead of its forecast replacement date. Please refer to the System Limitation Report for further information regarding the preferred network investment.

A demand side initiative to reduce the forecast maximum demand load by 31.4 MW at B zone substation would defer the need for this capital investment by one year.

14.1.5 Fisherman's Bend (FB) Zone Substation 11kV No1, 2 & 3 Bus J18/J22 Circuit Breakers

The Fisherman's Bend (**FB**) zone substation is served by 66KV sub-transmission lines from the Fisherman's Bend terminal station (**FBTS**) in a loop with Westgate zone substation (**WG**). The three 20/30 MVA 66/11kV transformers feed three 11kV bus sections comprised of sixteen 11kV feeders supplying the Port Melbourne area.

The 11KV bus consists of old non arc fault contained Email J18 and J22 oil filled circuit breakers installed at transformer incomers, bus section ties and feeder positions in service from 1969. The current CBRM model has determined that these circuit breakers indicate a health index of 43.97 and projected health index of 4.57 in next five years, and is nonetheless forecast to require replacement in 2025.

Currently this switchgear is inspected and tested according to twelve yearly maintenance plans. A circuit breaker failure will risk the reliability of the network due to the inadequate spare parts availability and the unavailability of internal and external skilled resources to repair these old assets safely.

According to the zone substation switchgear asset class strategy, CitiPower plans to reduce the population of non arc fault contained oil filled old circuit breakers from the network to significantly reduce the associated safety and reliability risks in event of an oil filled circuit breaker failure.

CitiPower estimates that with all the 11kV J18 & J22 Circuit Breakers at FB zone substation retired at the end of their lifetime in 2025 the entire zone substation or 33.7 MVA of load will be at risk and for 8760 hours it will be unable to supply any customers.

To address the anticipated constraints at FB zone substation switchboards, CitiPower considers that the following options could be implemented to manage the risk:

- replace Email J18 & J22 circuit breakers at FB zone substation with SF6 or Vacuum type new circuit breakers for an estimated cost of \$1.7 million
- transfer load away via 11 kV links to adjacent zone substations up to a maximum capacity of 1.6 MVA if a circuit breaker fails in the interim.

Given recent offline testing of the switchboard shows the insulation is in good condition, CitiPower's preference is to replace the J18 & J22 circuit breakers within the existing switchboard.

A demand side initiative to reduce the forecast maximum demand load by 33.7 MW at FB zone substation would defer the need for this capital investment by one year.

14.1.6 North Richmond (NR) Zone Substation Transformer 2

The North Richmond (**NR**) zone substation is served by two 66kV sub-transmission lines from Richmond terminal station (**RTS**) in a loop with Collingwood (**B**) zone substation. The substation currently comprises of two 66/11kV 23/28MVA transformers in service from 1958 and one 20/27 MVA transformer which was replaced in year 2000. The NR zone substation supplies the Richmond and North Richmond areas.

The transformer CBRM analysis determined that the No2 transformer has a high health index of 5.5 rising to 6.2 in the next five years. Further, in parallel to the replacement of the No2 transformer activities, the No.1 transformer will be commenced that will be completed beyond the forecast period. The No2 transformer activities are expected to be completed by 2026. With the No2 transformer retired, CitiPower estimates that in 2027 there will be 21.2 MVA of load at risk and for 678 hours in the year it will not be able to supply all customers from the zone substation if there is a failure of one of the two remaining transformers at NR.

To address the anticipated system constraint at NR zone substation, CitiPower considers that the following network solutions could be implemented to manage the risk:

- replace No2 transformer at NR with a new transformer of similar rating for an estimated cost of \$3.7 million
- Transfer load away via 11 kV links to adjacent Collingwood (**B**), (**CL**) and Kew (**Q**) zone substations up to a maximum capacity of 3.3 MVA should the transformer fail in the interim.

CitiPower's preferred option is to replace the No2 transformer at NR in 2026. The use of contingency load transfers will mitigate the risk should the asset fail ahead of its forecast replacement date.

A demand side initiative to reduce the forecast maximum demand load by 21.2MW at NR zone substation would defer the need for this capital investment by one year

14.1.7 Toorak (TK) Zone Substation 11kV No1 & 2 Bus J18/J22 Circuit Breakers

The Toorak (**TK**) zone substation is served by 66KV sub-transmission lines from the Richmond terminal station (**RTS**) in a loop with Balaclava zone substation (**BC**). This is a three transformer zone substation with 20/30 MVA, 66/11kV transformers feed three 11kV bus sections consisting a mix of Email and Reyrolle oil filled circuit breakers. This project is to replace existing Email J18/ J22 oil filled circuit breakers from bus section 1 and 2.

The 11KV bus section 1 and 2 consists of old non arc fault contained Email J18 and J22 circuit breakers installed at bus ties, transformer incomers and feeder positions in service for 51 years. The current CBRM model has determined that these circuit breakers indicate a health index of 4.15 and projected health index of 4.75 in next five years and is nonetheless forecast to require replacement in 2026.

Currently this switchgear is inspected and tested according to twelve yearly maintenance plans. A circuit breaker failure will risk the reliability of the network due to the inadequate spare parts availability and the unavailability of internal and external skilled resources to repair these old assets safely.

According to the zone substation switchgear asset class strategy, CitiPower plans to reduce the population of non arc fault contained oil filled old circuit breakers from the network to significantly reduce the associated safety and reliability risks in event of an oil filled circuit breaker failure.

CitiPower estimates that with the bus 1 and 2 11kV J18 & J22 Circuit Breakers at TK Zone Substation retired at the end of their lifetime in 2026 there will be 50.9 MVA of load at risk and for 8760 hours it will be unable to supply all customers.

To address the anticipated constraints at TK zone substation switchboards, CitiPower considers that the following options could be implemented to manage the risk:

- replace bus 1 and 2 Email J18 & J22 circuit breakers at TK zone substation with SF6 or Vacuum type new circuit breakers for an estimated cost of \$1.2 million.
- Transfer load away to adjacent zone substations via 11kV links to Richmond (**R**), Balaclava (**BC**), Armadale (**AR**) zone substations up to a maximum transfer capacity of 27.4MVA should a circuit breaker fail in the interim.

Given recent offline testing of the switchboard shows the insulation is in good condition, CitiPower's preference is to replace the J18 & J22 circuit breakers within the existing switchboard.

14.1.8 West Melbourne terminal station (WMTS) 22kV sub-transmission network

The West Melbourne terminal station (**WMTS**) proposed works are detailed in section 10.1 above. It is comprised of two transformers that each has a capacity of 165MVA operating at 22kV and four transformers that each has a capacity of 150MVA operating at 66kV. The 22kV connection is used by CitiPower however the 66kV load is shared by CitiPower (79 per cent) and Jemena Electricity Networks (21 per cent).

AusNet Services are undertaking significant works to rebuild WMTS due to the condition and age of the plant and equipment. As part of these works, AusNet Services proposed to rebuild the 22kV switchgear given its deteriorated condition.

CitiPower's 22kV sub-transmission network is also aged and deteriorated, particularly the transformers and indoor switchgear within existing zone substations. Some of these zone substations also have a secondary voltage of 6.6kV that is inconsistent with the current standard of 11kV used in those areas. CitiPower's strategy is to progressively replace the 22kV sub-transmission network with the 66kV sub-transmission network and convert existing 6.6kV distribution feeders to 11kV.

To reduce the cost of rebuilding WMTS, AusNet Services will now retire the 22kV supply assets which include transformers and switchgear. This is consistent with CitiPower's strategy.

CitiPower's 22kV WMTS sub-transmission network included Bouverie St/Bouverie Queensberry (**BSBQ**), Spencer St (**J**), Laurens Street (**LS**) and Dock Area (**DA**) zone substations. As per the preferred strategy below, BSBQ was transferred to Bouverie/Queensberry (**BQ**) during 2017 and decommissioning completed at the end of 2017. J was transferred to Little Bourke St (**JA**) during 2020 and decommissioning completed at the end of 2020. As a consequence of offloading J, the adjacent Tavistock

Place (**TP**) 22/6.6kV zone substation lost its 6.6kV ties. Rather than upgrading TP to 66/11kV in the short term, the TP feeders were transferred to the Little Bourke St (**JA**) and Victoria Market (**VM**) 66/11kV zone substations during 2020-2021 and decommissioning completed in 2021.

The following table details the deterioration in health indexes of the transformers at the above zone substations which are high indicating an elevated risk of failure:

Table 14.2 CitiPower WMTS 22kV zone substation health indices

Zone substation	2020 Health Index		2025 Health Index (no augmentation)	
	Transformers	Switchgear	Transformers	Switchgear
Dock Area (DA)	N/A, 5.50, 5.78	3.69	N/A, 6.18, 6.49	4.33
Laurens St (LS)	5.46, 5.16, 5.61	5.78	6.35, 6.03, 6.43	6.65

In the absence of any alternative strategies, the scheduled 'like for like' replacements are outlined below:

- Dock Area (**DA**) zone substation also requires replacement of three transformers due to age and condition. The first transformer is planned to be replaced in 2022 and the remaining two transformers replaced in 2024 and 2037.
- Laurens Street (**LS**) zone substation 'end of life' replacement of the 6.6kV switchgear was originally scheduled in 2012 however this has been delayed due to inability to offload to enable replacement to take place.

An alternative and preferred strategy is to retire the 22kV sub-transmission network earlier than scheduled, by offloading the Bouverie St/Bouverie Queensberry (**BSBQ**), Spencer St (**J**), and Laurens Street (**LS**) zone substations served by WMTS 22kV assets, and upgrade the Dock Area (**DA**) zone substation to 66kV with supply from WMTS 66kV, in collaboration with the AusNet Services rebuild of WMTS.

The Vic Rail (**VR**) customer substation will also need to be transferred to the WMTS 66kV point of supply.

The impact of no alternative supply for WMTS 22kV sub-transmission supplied zone substations is as follows:

- At DA zone substation, CitiPower will be unable to supply all load and customers when 22kV supply from WMTS is retired. This would lead to an unserved load of 28.5 MVA for 8760 hours in the year. The reduction in demand to defer the project would be 26.7 MW.
- At LS zone substation, CitiPower will be unable to supply all load and customers when 22kV supply from WMTS is retired. This would lead to an unserved load of 12.7 MVA

for 8760 hours in the year. The reduction in demand to defer the project would be 12.3 MW.

The exact timing of these works is currently being co-ordinated with AusNet Services, and the table below provides the estimated timing and cost of the major components of this plan. DA No.1 transformer has been removed in 2021 and the remaining two transformers are planned to be retired and removed in 2022. LS transformers are also planned to be offloaded and retired in 2022.

As these works are driven by asset replacement needs, CitiPower considers these works to be non-demand driven augmentation.

Table 14.3 WMTS 22kV offload plan

Zone substation	Description	Direct cost estimate (\$ million)				
		2022	2023	2024	2025	2026
Laurens St (LS)	Permanently transfer the entire LS load to the BQ zone substation, by extending 11kV high voltage feeders from LS to BQ (approved in 2017)	4.0				
Dock Area (DA)	Upgrade DA and associated sub-transmission cables to 66kV	5.8				

CitiPower and AusNet Services have identified that the costs to offload the 22kV network are far lower than replacing the existing aged 22kV assets and rectifying the building issues necessary to maintain the WMTS 22kV and associated sub-transmission network.

14.2 Group of assets

This section discusses planned retirements and replacements for groups of assets.

14.2.1 Poles and towers

CitiPower intends to replace poles and towers in various locations across the network in each year of the forward planning period. The number of poles and towers replaced each year is determined by condition assessments undertaken on each pole/tower inspected. The forecast number of poles/towers to be replaced in the coming five years is expected to increase in line with changes to poles management policies. CitiPower has a range of poles in its network, including hardwood, steel and concrete, supporting different voltages of conductor. All towers on the network are steel lattice structures.

Poles and towers are assessed using the RCM methodology which forms an input into the CBRM model to inform the policy position. The inspection frequency is based on priority and

economic optimisation to deliver the legislative obligations under the Electricity Safety Act 1998. This methodology was discussed in the previous chapter. Where the pole or tower is inspected and found to be defective, and a routine maintenance option is not viable to remedy the defect, (i.e. pole reinforcement), it is necessary and prudent to replace the pole or tower.

14.2.2 Pole top structures

CitiPower intends to replace pole top structures in various locations across its network in each year of the forward planning period. Pole top structures includes the following assets, which are managed as set out below:

- Wood or steel cross arms are inspected at the same time as the pole using the RCM methodology discussed in the previous section.
- Insulators are generally made of porcelain, are inspected at the same time as the pole using the RCM methodology discussed in the previous section.
- Surge arrestors are attached to the pole and provide an alternate current path for the electricity to ground in the event of a lightning strike. These are generally replaced after they operate; otherwise they are replaced based upon age.
- Other pole top structure equipment include: fuses, dampers, armour rods, spreaders, brackets, etc. These are all inspected at the same time as the pole.

The number of pole top structures replaced each year is determined by condition assessments undertaken on each pole top structure inspected. The forecast number of pole top structures to be replaced in the coming 5 years is expected to increase in line with changes to pole top management policies.

14.2.3 Switchgear

Switchgear can be classified as overhead or ground-mounted. Switchgear includes the following assets:

- automatic circuit reclosers (**ACR**) interrupt fault current and automatically restore supply after a dead time in the event of a transient fault
- air-break switches (**ABS**) use air as an insulating medium to interrupt load current
- gas switches use SF6 gas as an insulating medium to interrupt load current
- oil switches use mineral oil as an insulating medium to interrupt load current
- isolators use air as an insulating medium to interrupt load current.

Switchgear assets are replaced based on condition, which is monitored through routine maintenance and inspection. When a defect is found and it cannot be rectified through maintenance, a refurbishment or replacement of the asset is prudent.

The replacement need and timing are prioritised through risk and economic assessments. The location and the timing of the asset retirement is only determined when a defect is identified.

CitiPower intends to replace most¹¹ switchgear assets in each year of the forward planning period in line with historical volumes for most assets. Line mounted Air-break switches are now replaced with gas switches in place of cyclic maintenance or defect repair activities which is above the historical replacement volumes. This change has been implemented to address key issues such as operational delivery inefficiencies and inability to maintain the assets due to equipment obsolescence.

14.2.4 Overhead services

Overhead services, which are required to connect a customer supply point to the network are inspected at the same time as the pole and pole top structures using the same RCM methodology discussed in the previous sections.

CitiPower intends to replace overhead services in various locations across its network in each year of the forward planning period. The number of overhead services replaced each year is determined by condition assessments undertaken on each overhead service inspected. The forecast number of overhead services to be replaced in the coming 5 years is expected to increase above the historical replacements due to safety issues associated with deteriorated insulation on twisted grey PVC (and the “dog-bone” terminations) and open wire systems. In addition to these, the continued use of AMI meter analytics to detect, assess and replace services where the neutral is suspect, to address safety issues.

14.2.5 Overhead conductor

Overhead conductors are an integral part of the distribution system. Overhead conductors may be bare, covered or insulated and are made of aluminium, copper and galvanised steel.

Conductor replacements are based on two methodologies:

- through inspection, asset failures or defect reports
- proactively through risk-assessment using health indices.

CitiPower plans to replace sections of overhead conductors each year over the forward planning period. The location and the timing of the conductor replacement will be determined based on condition assessments. The forecast number of sections of overhead conductor to be replaced in the coming 5 years is in line with historic replacements with an expected increase from 2024. As data and modelling improves, a better understanding of the location and timing of the conductor replacement at the planning stage of the proactive replacement programme is expected in the near term.

In addition CitiPower plans to address insulation deficiencies around foreign objects such as sewer vents.

14.2.6 Underground sub-transmission cable

Underground sub-transmission cables are performance monitored and condition assessed by a scheduled cyclic testing program. Cables found by the test program to be in

¹¹ All switchgear with the exception of line mounted Air-break switches

unacceptable condition are generally repaired as the issue is normally location specific or the result of damage by third parties. Sections of cable may be replaced from time to time on an unplanned basis as a response to identified defects or damage. No sub-transmission cables are planned for replacement due to condition in the next five year period.

HV and LV Underground cables are performance monitored and condition assessed when the cable is exposed for augmentation works or defect repairs. Cables identified in unacceptable condition are prioritised for replacement using an economic assessment of risk associated with the identified defect.

Over the forward planning period CitiPower plans to replace underground cables in line with historical volumes.

14.2.7 Other underground assets

Other underground assets include the following:

- Cable-head termination, which is the termination of an underground cable. Over the forward planning period CitiPower plans to replace aged metal box type terminations in line with historical volumes.
- Distribution service pits are the point where the underground service connects to the customer premises, typically of concrete and plastic construction. Repairs and replacements are to be in line with historical volumes.
- CBD roadways pits are access points for HV distribution feeders and communication cables which are situated under roadways within the CitiPower CBD network. These assets are of concrete, steel brick construction. Over the forward planning period CitiPower plans to repair or replace large roadway pits due to an increase in identified structural defects from routine inspection activities. Repair and replacements are planned to be more than historical volumes.
- Low-voltage pillars are typically concrete or steel, where low voltage underground cables are terminated. CitiPower plans to replace or refurbish large type LV distribution pillars due to identified defects and condition in line with historical volumes.
- Services (underground), which are required to connect a customer supply point (underground pit) to the network, are replaced as a result of defect reports

Underground asset replacements are prioritised using an assessment of risk associated with the identified defect. The timing of replacement is determined by the risk assessment.

14.2.8 Distribution plant

In the forward planning period, CitiPower plans to replace distribution plant assets in line with historical volumes. Distribution plant assets include a variety of assets listed below:

- HV Circuit breakers (22kV, 11kV and 6.6kV) which are required to interrupt load or fault current are replaced based on the CBRM results, as explained in the previous chapter.

- Distribution substation transformers include indoor, kiosk, ground mounted (compound) or pole mounted types. Transformers are replaced based on condition, as identified through scheduled inspections and defect reporting. Replacement prioritisation is determined by conducting risk and economic assessments.
- Ring Main Units, which are banked switching units that enable switching between three or more underground cables, replacement is managed by the following strategies.
 - **Unplanned** - on condition identified by scheduled inspection and defect reports.
 - **Planned** - through prioritised risk based replacement using the implemented CBRM model.
- Earthing cables, which are required as one measure to prevent de-energised assets from becoming energised in the event of insulation breakdown or contact with live assets, are replaced following an inspection and/or condition monitoring.
- Combination switches, which are a high voltage switch and fuse combined, are replaced based on age with prioritisation of replacement determined by economic and risk assessment, given that neither the condition nor performance can readily be measured.

The location and the timing of the replacement of distribution plant assets are determined at the time of inspection and detection of defect, or upon failure of the asset.

14.2.9 Zone substation switchyard equipment

In the forward planning period, CitiPower plans to replace station switchyard assets in line with historical volumes. Zone substation switchyard equipment assets include a variety of assets including those listed below:

- Surge arrestors, which are required to protect primary plant from voltage surges, are generally replaced after failure. They can also be replaced based on age and condition, or opportunistically where other asset replacements take place at the zone substation.
- Busses, which allow multiple connections to a single source of supply, are usually replaced as part of the associated zone substation equipment being replaced, e.g. 11kV busses usually form part of modular switchgear and thus are included as part of switchgear replacement.
- Joints, terminations and connector assets are replaced on inspection, or as part of the replacement of the assets to which they are connected.
- Steel structures, which are required to hold energised assets in place, are replaced based on inspection and observed condition.

The location and the timing of the replacement of zone substation assets are determined at the time of inspection or upon identification of defects.

14.2.10 Protection and control room equipment and instrumentation

Protection and control systems are designed to detect the presence of power system faults and/or other abnormal operating conditions and to automatically isolate the faulted network

by the opening of appropriate high voltage circuit breakers. CitiPower plans to replace protection and control room equipment and instruments each year over the forward planning period. This includes the following assets:

- Protection relays: are replaced based on age and/or economic assessment of risk.
 - CitiPower's relay replacement program focusses on electro-mechanical and electronic protection relays. The risk profile of these types of relays is forecast to significantly increase as the technology is approaching end of life.
 - Relays will be replaced at the following zone substations over the forward planning period: Albert Park (**AP**), Armadale (**AR**), Collingwood (**B**), Balaclava (**BC**), Camberwell (**CL**), Collingwood (**CW**), Fishermens Bend (**FB**), Deepdene (**L**), Little Queen (**LQ**), Montague (**MG**), Northcote (**NC**), Kew (**Q**), Riversdale (**RD**), South Melbourne (**SO**) and Westgate (**WG**).
 - As the need to replace the assets will be reassessed on a risk-based approach closer to the replacement period, the date of replacement is unknown at time of writing.
- Capacitor Bank controllers (or VAR controllers), are usually run-to-failure and as such it is prudent for CitiPower to maintain asset spares.
- Battery banks are replaced based on the results of condition tests.
- Voltage/current transformers: are usually run-to-failure and as such it is prudent for CitiPower to maintain asset spares.

Aside from the proactive replacement of protection relays at zone substation locations, the timing and the location of the replacement of other assets are determined through routine inspection and detection of defects, or upon asset failure.

14.3 Planned asset de-ratings

CitiPower has no planned asset deratings in the forward planning period.

14.4 Committed projects

This section sets out a list of committed investments worth \$2 million or more to address urgent and unforeseen network issues.

CitiPower does not have any committed projects to address urgent and unforeseen network issues.

14.5 Timing of proposed asset retirements / replacements and deratings

CitiPower is now also required to provide detailed information on its asset retirements / replacement projects and deratings in its DAPR as described above. The timing of these may change subject to updated asset information, portfolio optimisation and realignment with

other network projects, or reprioritisation of options to mitigate the deteriorating condition of the assets.

CitiPower has made improvements to the risk assessment quantification. These changes primarily involve a refinement of the estimated failure probability for transformers, taking into account failures and replacements, and the inclusion of analysis at a substation level, considering common-cause failure risk for substations with identical assets. As a result, some asset retirements have been deferred, and other future retirements have been brought forward.

The table below summarises the change in timing of proposed major network retirements/replacements.

Table 14.4 Changes in timing of asset retirements / replacements and deratings

Proposed Asset Replacement	2020 DAPR	2021 DAPR
Albert Park (AP) Zone Substation 11kV No1 Bus - J18/J22 Circuit Breaker	2024	2025
Armadale (AR) Zone Substation 1-2 LG4C 66kV Circuit Breaker	2022	removed
Celestial Avenue (WA) Zone Substation Transformer 1	2022	2024
Celestial Avenue (WA) Zone Substation Transformer 2	2023	2026
Collingwood (B) Zone Substation 11kV Email J18 HV Switchboard	2023	2024
Collingwood (B) Zone Substation 2-3 LG4C 66kV Circuit Breaker	2021	removed
Fishermans Bend (FB) Zone Substation 11kV No1 Bus - J18/J22 Circuit Breaker	2022	2025
Fishermans Bend (FB) Zone Substation 11kV No2 Bus - J18/J22 Circuit Breaker	2022	2025
Fishermans Bend (FB) Zone Substation 11kV No3 Bus - J18/J22 Circuit Breaker	2022	2025
Little Queen (LQ) Zone Substation 11kV Switchboard	2026	removed
North Richmond (NR) Zone Substation Transformer 1	2024	removed
North Richmond (NR) Zone Substation Transformer 2	2025	2026
Northcote (NC) Zone Substation 1-2 LG4C 66kV Circuit Breaker	2023	removed
South Melbourne (SO) Zone Substation 1-2 LG4C 66kV Circuit Breaker	2024	removed
Toorak (TK) Zone Substation 11kV No1 Bus - J18/J22 Circuit Breaker	2023	2026

15 Regulatory Tests

This chapter sets out information about large network projects that CitiPower has assessed, or is in the process of assessing, using the Regulatory Investment Test for Distribution (**RIT-D**) during the forward planning period.

This chapter also sets out possible RIT-D assessments that CitiPower may undertake in the future.

Large network investments are assessed using the RIT-D process. The RIT-D relates to investments where the cost of the most expensive credible option is more than \$5 million. The RIT-D has historically been used for large augmentation projects, and was extended to include replacement projects from 18 September 2017.

Transitional arrangements apply for the introduction of the RIT-D for replacement projects that have been “committed” to by a distributor on or prior to 30 January 2018. These projects are also listed in this chapter, as well as published on our website.¹² There is no material impact on connection charges and distribution use of system charges that have been estimated.

15.1 Current regulatory tests

There were no Regulatory Test projects underway or completed by CitiPower in 2021.

15.2 Future regulatory investment tests

Based on the information contained within sections 7, 8, and 14, CitiPower expects to commence reviewing options to address the identified system limitations. The table below sets out the possible timeframes for consideration of RIT-D under clause 5.17 of the NER relating to investments where the cost of the most expensive credible option is more than \$6 million.

¹² <https://www.citipower.com.au/network-planning-and-projects/network-planning/>

Table 15.2 Future RIT-D projects

Project name	Proposed RIT-D start date	Comments
Brunswick Area Strategy – Retirement of the 22kV sub transmission and 6.6kV distribution network	June 2024	Transfer of Fitzroy (F) zone substation load to Collingwood (CW) and Brunswick (BK) to West Brunswick (WB) zone substation and conversion to 11kV
Port Melbourne Area Strategy – Retirement of the 6.6kV network	June 2025	In accordance with the AER determination, this project is to be delivered post 2026. Transfer of Port Melbourne (PM) and Fishermans Bend (E) zone substations load to Westgate (WG) and conversion to 11kV
HV Switchboard Replacement B 11kV Email J18	November 2021	Replace the 11kV switchboard
HV Switchboard Replacement LQ 11kV Email HQ (Compound)	July 2022	Replace the 11kV switchboard
Western CBD and Docklands security strategy	June 2022	Significant reduction in forecast CBD load growth due to COVID-19 pandemic requires re-assessment and development of strategic options to meet project aim.

RIT-D consultation documents will be made available from the CitiPower website and notified to participants registered on the Demand Side Engagement Register.

15.3 Excluded projects

The table below provides a list of the excluded projects from the RIT-D under the transitional arrangements relating to the extension of the RIT-D to replacement projects.

Table 15.6 Excluded RIT-D projects

Project name	Description	Scheduled completion date
Decommission of Laurens Street (LS) zone substation	Transfer of load to BQ zone substation and decommission of LS zone substation. The LS zone substation assets are aged and poor condition. We have committed to decommissioning these 22kV sub-transmission assets rather than the more expensive option of replacing them. Required as part of the program to decommission the 22kV sub-transmission network from WMTS and replace with the 66kV network.	Project underway expected completion in Q2 2022

16 Network Performance

This chapter sets out CitiPower's performance against its reliability targets in 2020 and its plans to improve reliability over the forward planning period.

16.1 Reliability measures and standards

CitiPower is subject to a range of reliability measures and standards.

The key reliability of supply metrics to which CitiPower is incentivised under the Service Target Performance Incentive Scheme (**STPIS**) are:

- System average interruption duration index (**SAIDI**): Unplanned SAIDI calculates the sum of the duration of each unplanned sustained customer interruption (in minutes) divided by the total number of distribution customers. It does not include momentary interruptions that are one minute or less
- System average interruption frequency index (**SAIFI**): Unplanned SAIFI calculates the total number of unplanned sustained customer interruptions divided by the total number of distribution customers. It does not include momentary interruptions that are one minute or less. SAIFI is expressed per 0.001 interruptions
- Momentary average interruption frequency index (**MAIFI**): calculates the total number of momentary interruptions divided by the total number of distribution customers (where the distribution customers are network or per feeder based, as appropriate).

The reliability of supply parameters are segmented into CBD and urban feeder types.

The table below shows the reliability service targets set by the AER for CitiPower in its Distribution Determination in May 2016.¹³ CitiPower reported to the AER its 2020 performance against those targets in the 2020 calendar year in its Regulatory Information Notice (**RIN**), and these figures are included in the table. In addition, CitiPower has also forecast its outturn performance for the 2021 calendar year, based on actual performance for the period from 1 January 2021 to 30 September 2021, and then projected forward taking into account seasonal factors.

¹³ AER, CitiPower - Distribution Determination 2016–2020, Final, May 2016.

Table 16.1 Reliability targets and performance

Feeder	Parameter	AER target (2016-20)	2020 performance	2021 forecast performance (at 30 Sept 2021)
CBD	SAIDI	9.130	7.147	10.647
	SAIFI	0.129	0.136	0.108
	MAIFI	0.005	0.000	0.038
Urban	SAIDI	32.696	32.385	24.159
	SAIFI	0.484	0.442	0.316
	MAIFI	0.152	0.200	0.130

In 2020, CitiPower achieved its targets for CBD SAIDI & MAIFI and Urban SAIDI & SAIFI parameters.

In 2021, CitiPower is forecast to perform better than targets for all parameters except for the unplanned CBD SAIDI & MAIFI.

Actual network performance is also often influenced by external events such as storms, heat, flood, or third party damage which may be outside of CitiPower's control. The influence of these factors on network performance can also vary significantly from one year to the next.

16.1.1 Corrective reliability action undertaken or planned

Actual network reliability performance is the result of many factors and reflects the outcomes of numerous programs and practices right across the network. To achieve long term and sustainable reliability improvements, CitiPower continues to refine and target existing asset management programs as well as reliability specific works.

The processes and actions which CitiPower undertakes to sustain reliability include:

- undertaking the various routine asset management programs, including:
 - inspection of nearly 15,000 poles and pole tops
 - testing of lines such as sub-transmission cables in the CBD
 - maintenance and replacement programs for overhead and underground lines, primary plant (and secondary systems
 - civil works to restore zone substation buildings, switchrooms and transformer enclosures at various zone substations.
- deployment of portable auxiliary cooling fans at several substations to assist in cooling heavily loaded transformers

- targeted installation of smart technologies to improve network monitoring, control and restoration of supply including intelligent circuit reclosers, gas switches and line fault indicators at strategic locations
- targeted reduction of the exposure to faults on the distribution network by using:
 - thermography programs to detect over-heated connections
 - Partial Discharge detection program for indoor 6.6kV and 11kV switchgear in Zone substations including several continuous on line monitoring systems
 - vegetation management programs to improve line clearances
 - animal and bird mitigation measures to reduce the risk of 'flash-overs'
 - targeted insulator washing and pole-top fire mitigation to reduce the risk of pole fires
 - dehydration of power transformer.
- use of innovative solutions such as auxiliary power generation or by-pass cables to maintain supply where practicable
- conduct fault investigations of significant outages to understand the root cause, in order to prevent a re-occurrence
- undertake asset failure trend analysis and outage cause analysis to identify any emerging asset management issues and to mitigate those through enhancing the related asset management plans, maintenance policies or technical standards.

CitiPower has invested \$0.2m in reliability improvement through the addition of automated devices and expansion of Fault Detection, Isolation and Restoration (FDIR) on the network. It should be noted that in reference to all of the initiatives listed in chapter 16.1.1, automation only represents a fraction of the business investment in network performance.

Evaluation of the 2021 reliability improvement initiatives should be considered in the context of the longer term goals stipulated above and the volatility caused by uncontrollable events such as severe storms and the effect of third party events.

Reliability metrics, such as SAIDI, SAIFI and MAIFI, as well as guaranteed service levels (GSLs), are used to monitor the network reliability performance. By monitoring network performance against these metrics, it confirms that CitiPower's programs are maintaining and/or improving our reliability risk at a network level with 2021 performance materially exceeding AER targets.

Each year CitiPower evaluates recent performance so that it can:

- identify trends in network performance and reliability across the network
- identify initiatives to bridge the gap between current and desired performance.
- maintain the level of network performance (and customer experience) at the existing levels and at the lowest cost but improve performance where it is economically justified

-
- manage the customer experience by seeking to limit both the number and duration of outages experienced by individual customers, and to improve the reliability performance to our worst served customers by focusing on local issues.

To achieve these objectives when managing the distribution network, a basic reliability model is applied by focusing on:

- preventing outages from occurring
- minimising the number of customers affected by each outage event
- restoring supply as quickly as possible
- analysing and improving individual customer experience.

16.2 Quality of supply measures and standards

The main quality of supply measures that CitiPower control are:

- voltage, including measuring customer voltage and network voltage using AMI data
- harmonics.

16.2.1 Voltage

Voltage requirements are governed by the Electricity Distribution Code and the NER.

The NER essentially requires that CitiPower adheres to the 61000.3 series of Australian and New Zealand Standards.

In addition, the Electricity Distribution Code requires that CitiPower must maintain nominal voltage levels at the point of supply to the customer's electrical installation in accordance with the Electricity Safety (General) Regulations 2019 or, if these regulations do not apply to the distributor, at one of the following standard nominal voltages:

- (a) 230V
- (b) 400V
- (c) 460V
- (d) 6.6kV
- (e) 11kV
- (f) 22kV or
- (g) 66kV.

Variations from the standard nominal voltages listed above are permitted to occur in accordance with the following table:

Table 16.2: Permissible voltage variations¹⁴

STANDARD NOMINAL VOLTAGE VARIATIONS					
	Voltage Level in kV	Voltage Range for Time Periods			Impulse Voltage
		Steady State	Less than 1 minute	Less than 10 seconds	
1	< 1	AS 61000.3.100*			6 kV peak
2		+13% - 10%		Phase to Earth +50%, -100% Phase to Phase +20%, -100%	
3	1 – 6.6	± 6 %	± 10%	Phase to Earth +80%, -100% Phase to Phase +20%, -100%	60 kV peak
4	11	(± 10 %			95 kV peak
5	22	Rural Areas)			150 kV peak
6	66	± 10%	± 15%	Phase to Earth +50%, -100% Phase to Phase +20%, -100%	325 kV peak

CitiPower must use best endeavours to minimise the frequency of voltage variations allowed for periods of less than 1 minute (other than in respect of AS 61000.3.100 where the time period of less than one minute does not apply).

CitiPower is able to measure voltage variations at zone substations, as many have power quality meters installed. This enables CitiPower to address any systemic voltage issues. The table below provides the number of instances of voltage variations at CitiPower zone substations in the 2020-21 financial year, although many of these instances would have occurred from abnormalities or transients in the system.

Table 16.3 Zone substation voltage variation in 2020-21 FY

Voltage variations	Number of occurrences
Steady state (zone substation)	107
One minute (zone substation)	1
10 seconds (zone substation) Min<0.7	95
10 seconds (zone substation) Min<0.8	7
10 seconds (zone substation) Min<0.9	33

CitiPower responds quickly to investigate and resolve voltage issues. The issues may be identified through the system monitoring undertaken by CitiPower or as a result of customer complaints. The Supply Quality team may subsequently carry out projects to address concerns relating to voltages.

¹⁴ Table 1 Clause 4.2.2 of the electricity distribution code.

The solutions that CitiPower may adopt include:

- installation of voltage regulators which will bring voltage levels at customer connection points within the applicable requirement
- the upgrade of existing distribution transformers, or the installation of new distribution transformers, to increase the ability of the network to meet customers' demand for electricity and improve voltage performance
- replacing small sized conductors with large conductors in order to improve the voltage performance, or
- installation of additional reactive power compensation, such as capacitor banks, to improve voltage performance.

CitiPower may also identify issues with voltage following applications from potential “disturbing load” customers, such as an embedded generator or a large industrial customer, to connect to the network. System studies are carried out on a case-by-case basis to identify voltage or harmonic constraints relating to proposals, with recommendations for corrective action provided to the party seeking to connect.

16.2.2 Customer voltage performance at low voltage

AS 61000.3.100 (as referenced in chapter 16.2.1) requires that the 99th percentile voltage at the customer's point of connection must be less than 253V and the 1st percentile voltage must be above 216V. This is a deviation from the previous requirements that stipulated a hard limit of 216V and 253V. The Code also stipulates that the distributors would be liable for equipment and property damages should the steady-state voltage be found to operate outside 207V and 260V. AS 61000.3.100 also recognises that for distribution companies like CitiPower, with hundreds of thousands of customers spread over a large geographic area, that achieving 100% compliance for all customers at all times is not economically or practically possible. Therefore a network is considered to be ‘functionally compliant’ if it can achieve voltage within each limit for 95% of sites.

Figures 16.2.2 and 16.2.3 below show CitiPower's performance for both 99th percentile voltage (V99%) and 1st percentile voltage (V1%) with respect to the 95% functional compliance target.

Figure 16.2.2 Monthly V99% 253V Customer Compliance

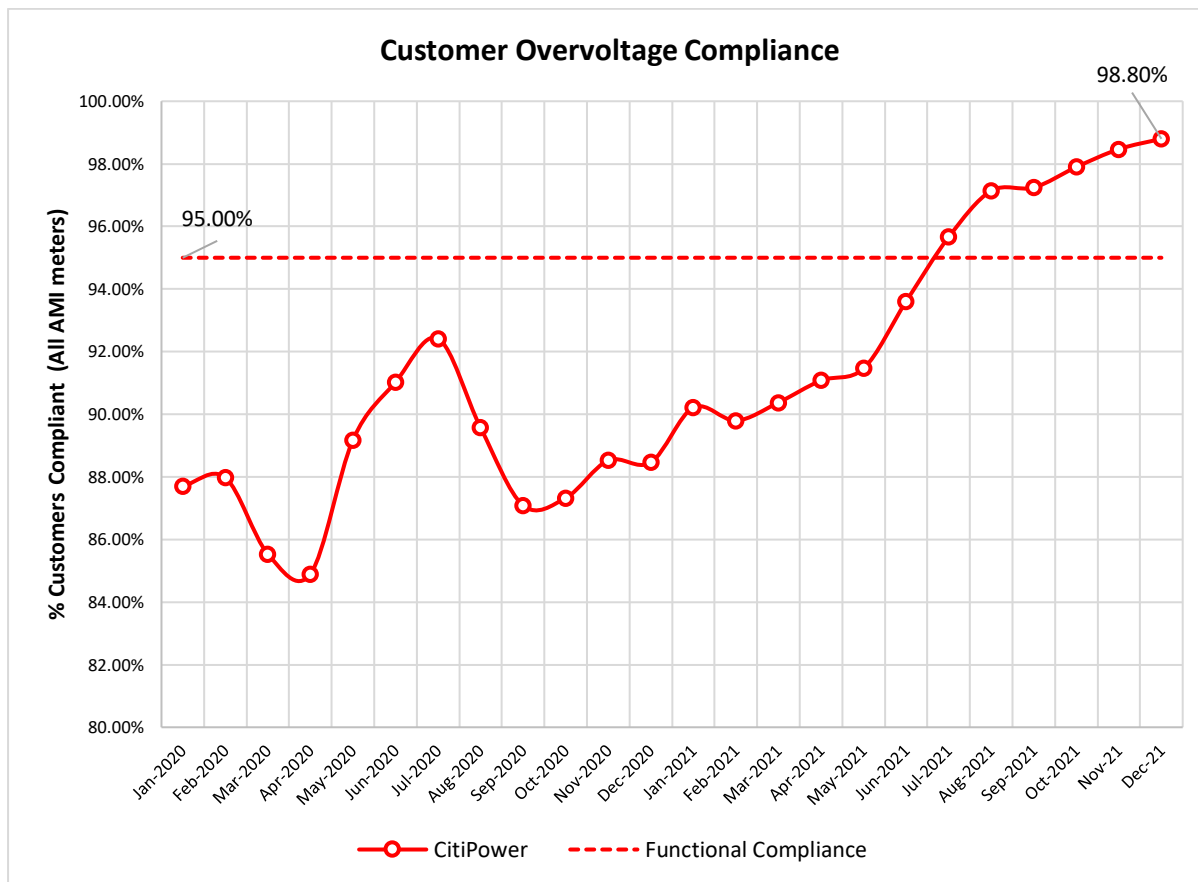
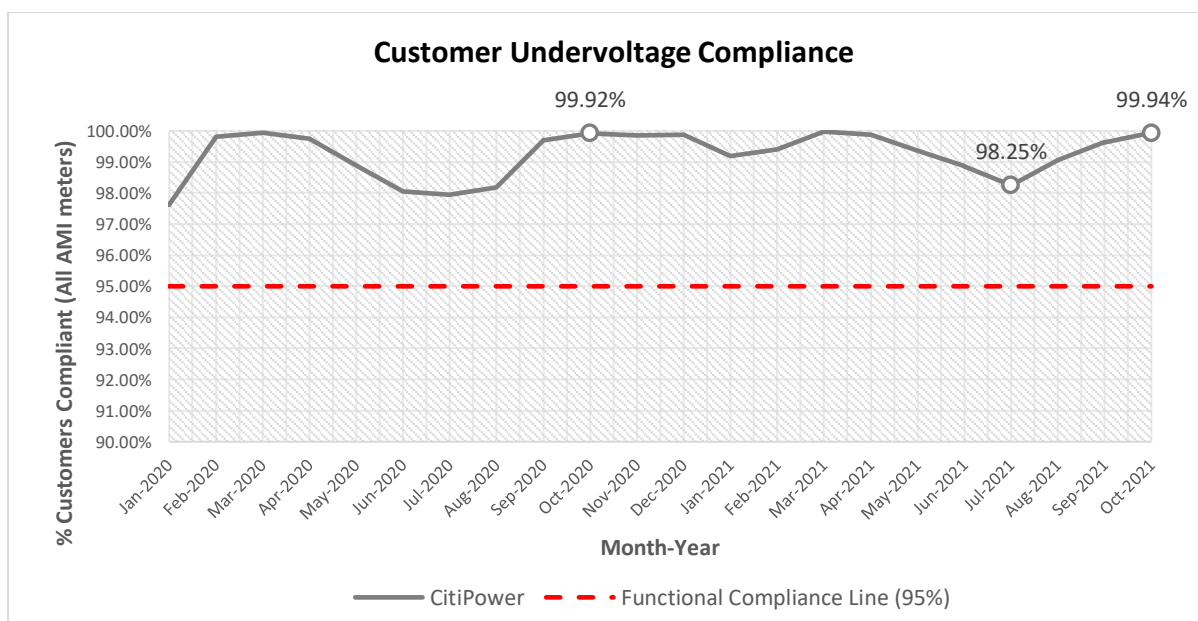


Figure 16.2.3 Monthly V1% 216V Customer Compliance



As noted in Section 3.7, CitiPower is undertaking numerous steps to improve customer voltage and have significantly increased works in 2021 with CitiPower's 5-year Solar Enablement program. As a result, V99% performance has demonstrably improved year-on-

year (i.e. comparison of June 2020 vs. June 2021). It should be noted there is seasonal and monthly variability to V99% performance and hence a year-on-year evaluation approach is taken to assess the impact of improvement works. Additionally, in 2021 CitiPower have undertaken a significant engagement with manufacturers, installers, and customers that have identified issues, to rectify solar PV installations and inverter setting issues, and improve installation compliance going forward. Using AMI meters, CitiPower identified that the majority of installations were not implementing smart inverter settings which act to bring down the voltage and enable more solar PV onto the network. Through this engagement we have rectified issues and improved installation compliance which has also contributed to the improvements in voltages in 2021 as above. This will be a continued focus going forward, as achieving near 100% installation compliance is crucial to maximising the amount of rooftop solar on the network while improving network wide functional voltage compliance.

Going forward, to improve and maintain voltage compliance CitiPower will:

- invest in new systems, including the Dynamic Voltage Management System (DVMS) to manage network voltages in real time based on feedback from our AMI meters to optimise customer volts;
- invest in the network, by continuing to identify works that improve customer voltage and deliver extra hosting capacity;
- prepare the detailed program of works and overarching program design for the longer term deployment of the solar enablement program.

16.2.3 AMI voltage data

CitiPower is required to report AMI voltage information, as specified in Schedule 1 of the Electricity Distribution Code.

The voltage information required to be published is for each voltage-controlled section of the network, which is defined as any device or equipment that manages the distribution feeder voltage, starting from the zone substation. Voltage information is therefore required and provided for each of CitiPower's distribution feeders given it has no in-line voltage regulators.

The voltage data to be published for each section is the aggregated 10-minute average voltage data, aggregated over 3 months periods (December-November), by time of day into 6 hour periods (from 4am to 4am). Under the requirements of the Section 3.5 of the Victorian Electricity Distribution Code (the Code) this planning report is required to include all of the information provided in Schedule 1 of the Code.

The CitiPower dataset provided is the average of all customers connected to the relevant feeder and regulator section. The averages are calculated by taking the average across all customers for each 15 minute block within each day of the year. Those 15 minute averages are then grouped into the season and time period and averaged for the report.

Due to legacy configuration of AMI meters CitiPower is not able to provide a 5-year rolling history of 10-minute interval voltage information observed on the low voltage network the time of publication of this report. CitiPower is making changes to systems and processes which will be completed in 2022 to enable the collection of data required to meet the requirement moving forwards. Until the data is available CitiPower will provide 15-minute

data from January 2017 onwards. In the year where 10-minute data becomes available the reporting will be modified so that reports moving forward contain the 10-minute data.

CitiPower's data is sorted by year and month and can be found by accessing the link shown below and searching for LV voltage reports:

<https://spaces.hightail.com/space/UaPnYI6yeV>

For avoidance of any doubt, blanks in the data reflect changes in the network that cause a feeder to be out of service for an entire quarter. These changes include but are not limited to:

- establishment of a new zone substation
- decommissioning of an existing zone substation
- long duration (3 months) transfers while the network is being re-arranged and then returned to normal state

16.2.4 Harmonics

Voltage harmonic requirements are governed by the Electricity Distribution Code and the NER.

The NER essentially requires that CitiPower adheres to the 61000.3 series of Australian and New Zealand Standards.

CitiPower uses the Indicative Planning Levels for Harmonic Voltages as provided in Table 2 of the Australian Standard AS/NZS 61000.3.6:2001 and given below:

Table16.4 Voltage harmonic distortion planning levels

Odd Harmonics (non-multiple of 3)			Odd Harmonics (multiple of 3)			Even Harmonics		
Order h	Harmonic Voltage (%)		Order h	Harmonic Voltage (%)		Order h	Harmonic Voltage (%)	
	6.6-22kV	66-220 kV		6.6-22kV	66-220 kV		6.6-22kV	66-220 kV
5	5	2.0	3	4	2.0	2	1.6	1.5
7	4	2.0	9	1.2	1.0	4	1	1.0
11	3	1.5	15	0.3	0.3	6	0.5	0.5
13	2.5	1.5	21	0.2	0.2	8	0.4	0.4
17	1.6	1.0	>21	0.2	0.2	10	0.4	0.4
19	1.2	1.0				12	0.2	0.2
23	1.2	0.7				>12	0.2	0.2
25	1.2	0.7						
>25	0.2 + 0.5 (25/h)	0.2 + 0.5 (25/h)						
Total harmonic voltage distortion contribution at 6.6-22kV: 6.5% and 66-220 kV: 3% Non-integer harmonic voltage contribution: 0.2%								

CitiPower responds quickly to investigate and resolve voltage issues. The issues may be identified through the power quality meters that CitiPower has installed to monitor the quality of supply or as a result of customer complaints. The Supply Quality team may subsequently carry out projects to address concerns relating to voltages.

Where the voltage harmonics are measured to be consistently outside of the required levels, CitiPower will investigate and resolve the issue. The solutions that CitiPower may adopt include:

- alter the switching sequencing of the network equipment to reduce the voltage harmonic distortions
- replacing small sized conductors with large conductors in order to improve the voltage harmonic performances, or
- installation of harmonic filtering equipment to improve voltage harmonic performance.

Customer and generator operations can also affect power quality to other customers connected in the broader network. CitiPower works with its customers to ensure their facilities operate in accordance with agreed rules and regulations. This ensures all customers have a positive and equitable experience of the network.

17 Embedded Generation and Demand Management

This chapter sets out information on embedded generation as well as demand management activities during 2021 and over the forward planning period.

17.1 Embedded generation connections

The table below provides a quantitative summary of the connection enquires under chapter 5 of the NER and applications to connect EG units received in 2021.

Table 17.1 Summary of embedded generation connections

Description	Quantity (> 5MW)
Connection enquires under 5.3A.5	0
Applications to connect received under 5.3A.9	0
The average time taken to complete application to connect	N/A

Key issues to connect embedded generators to CitiPower's network include:

- available capacity of the sub-transmission network is limited due to the existing and committed large-scale generators
- fault levels in the Melbourne CBD and tight allocations where applicants have sought to connect in dense supply areas.

17.2 Non-network options and actions

CitiPower actively seeks opportunities to promote non-network alternatives for both general and project-specific purposes. Up to summer 2021/22, the following details some of CitiPower's activities:

- CitiPower monitors industry developments and engages with providers of demand management and smart network technologies
- Over the next year CitiPower is actively exploring opportunities in the industry of Electric Vehicles (**EV**) technology and use cases. The purpose will be to determine

future network effects of large uptake of the technology by customers as well as a variety of other considerations.

- In 2021, CitiPower is trialling a 'Summer Saver' program for customers to voluntarily reduce demand and be rewarded during peak periods on specific distribution substations in the network. This program is complemented by 'Energy Partner' program initiated in 2020 which allows us to directly control participating customers' air-conditioning load. CitiPower is open to collaborate with partners who can add value to the programs from customer experience perspective while delivering network benefit cost-effectively.

Over the forward planning period, CitiPower intends to continue to consider demand side options via its Demand Side Engagement Strategy.

17.3 Battery Programs

CitiPower is supporting network owned and third party owned community batteries. These batteries will support increased DER hosting capacity as well as provide opportunities for third party investment into assets that support the networks as a non-network solution.

17.4 Demand side engagement strategy and register

CitiPower updated and published its Demand Side Engagement Strategy in July 2019. The strategy is designed to assist non-network providers in understanding CitiPower's framework and processes for assessing demand management options. It also details the consultation process with non-network providers. Further information regarding the strategy and processes is available from:

<https://www.citipower.com.au/network-planning-and-projects/network-planning/>

CitiPower has also established its Demand Side Engagement Interested Parties Register. The register was established in mid-2013. It currently allows interested parties to provide contact details and other relevant information, but will be enhanced in the near future to become an online form portal. To register as a Demand Management Interested Party, please email the following:

DMInterestedParties@CitiPower.com.au

In 2021, no formal submissions from non-network providers were received however there are a total of 124 registered entities, an increase of 4 from 2020.

18 Information Technology and Communication Systems

This chapter discusses the investments we have undertaken in 2021, or plan to undertake over the forward planning period 2022-2026, relating to information technology (IT) and communications systems.

18.1 Security Program

As new security threats emerge and grow over time, we keep investing in our cyber capabilities so we can continue protecting our network and our customers. Our ongoing cybersecurity program of works introduces increasingly sophisticated processes and systems that proactively prevent, detect, respond to, and recover from security threats that have the potential to disrupt critical services.

In early 2020, we refreshed our cyber security strategy and identified areas where we identified there were further opportunities to improve how we manage cyber security risks. A three-year program of works has been initiated that will enable us to achieve our cyber risk priorities through the delivery of targeted initiatives addressing a broad range of capabilities.

Our 2021 delivery program has focused on enhancing external security to reduce the likelihood of cyber security incidents that impact our IT network, that could result in third party incursions damaging our critical IT and Operation Technology (OT) systems. Improvements to email, web, physical network access and cloud-based security controls have been identified as priority areas, and will be fully addressed by mid-2022.

In parallel a transformational program that will improve our security operations capability (SOC) has commenced will be progressively implemented through 2022.

Our current cyber security strategy will be completed by 2025. We will also continue to align our security strategy and initiatives with relevant industry standards, such as the Australian Energy Sector Cyber Security Framework (AESCSF), National Institute of Standards and Technology (NIST) and authorities such as the Australian Signals Directorate (ASD) to ensure that controls implemented are consistent with recognised Australian and international best practices.

In addition, investment in the forward planning period is likely to be required to meet new security obligations expected to be imposed under the Security Legislation Amendment Bill 2021 and associated electricity sector regulations.

18.2 Currency

We routinely undertake system currency upgrades across our IT systems to reflect vendor software release life cycles and support agreements. These refresh cycles are necessary to ensure system performance and reliability are maintained, and that the functional and technical aspects of our systems remain current.

In 2021, we completed the UIQ upgrade. Due to the over-lapping system changes with five-minute settlement, the UIQ v5 upgrade had to be aligned to the five-minute settlement go live date in October 2021. The project ensured we would be able to achieve the five-minute settlement outcomes and remain compliant by supporting five-minute data functionality and achieving the required throughput in order to collect and process the volumes required to support five-minute settlement.

During the forward planned period for this DAPR, we will maintain the currency of the systems which manage our network (i.e. operational technology). This includes the geospatial information system (GIS), outage management systems (OMS), SCADA and distribution management system (DMS). Maintaining currency of these systems is essential to maintaining the safe, reliable, secure and efficient delivery of network services.

We will also maintain the currency of other systems, including our market systems, which support the provision of energy data to market, business intelligence and warehousing, telephony and enterprise market systems. Our customers view reliability, affordability and the privacy of their data as priorities.

18.3 Compliance

We are focused on ensuring that, as regulated businesses, our IT systems support all regulatory, statutory, market and legal requirements for operating in the National Electricity Market (NEM). These obligations are regularly amended by various government bodies and regulators to reflect the changing energy market. We ensure compliance through prudent investment in systems, data, processes and analytics that provide the requisite functionality and reporting capability to efficiently comply with statutory and regulatory obligations.

This year we implemented five-minute settlement for a compliance date of 1 October 2021, under which the settlement period for the electricity spot price is altered from 30 minutes to 5 minutes.

This program, included enhancing storage to handle significantly more data and changes to system architecture (e.g. Market Transaction System, Itron Enterprise Edition, CIS/OV, UIQ, Salesforce, SAP) as well as business and operational processes (e.g. billing, contract centres, reporting, network, advanced metering infrastructure (AMI) operations and network analytics).

We have now begun Phase 2 of the five-minute settlement program which ensures AMI meter fleet installed after 1 December 2018 are configured to collect and send data in 5 minute intervals by 1 December 2022. Phase 2 includes:

- Upgrading of all key metering applications to be five-minute settlement compliant
- Ensure all required meters are collecting data in five minute intervals
- Ensure the business meets the meter data provider (MDP) accreditation for five minute AMI metering.

Alongside the five-minute settlement program, we delivered the global settlement program. The global settlement amendments change remove the requirement for the host retailer to be accountable for all unaccounted for energy.

This year we also updated our key market systems to ensure compliance with new procedures formulated by the AEMC to accelerate the process for customers to transfer to a new retailer by 1 October 2021.

In addition, the new regulatory period commenced on 1 July 2021 required changes to our alternative control service (ACS), quoted services charges and network tariffs. Prior to 1 July 2021 we were required to make included:

- Changes in service classifications and ACS fee categories to align with the final determination
- Updated, in partnership with our vendors, relevant market systems to reflect the updated ACS charges and introduced new product codes to align with the final determination
- Amended the billing and market data system to address changes in how the demand component of our network tariffs is calculated, including the addition of seasons and a summer incentive demand component
- Amended residential and small business network tariffs from Australian Eastern Standard time to local time
- Closed a number of network tariffs and migrated customers on these network tariffs to new network tariffs.

In the forward DAPR planning period, we will continue to implement compliance projects as these arise. We will also continue to amend our system and data controls to ensure customer, employee and asset data remains hosted in Australia.

18.4 Infrastructure

We have an increasing need to store and recall data, as well as support applications, processes and functions across our IT systems. To support this, we must ensure our IT infrastructure remains technically current, meets relevant security requirements and meets our service level requirements to our customers and energy markets.

During 2021 we established new applications, supported by cloud-hosted infrastructure, while retaining our existing infrastructure on premise. In 2021 we also invested in positioning our infrastructure to support five-minute settlement, which will greatly increase our data volume collection requirements to support other IT applications.

This included:

- Consolidated our Oracle databases onto a new generation, higher capacity, Oracle Exadata platform to support the additional data volumes that will occur when five-minute settlement is enabled
- Deployed additional storage and data backup infrastructure to accommodate growing data volumes
- Refreshed critical network infrastructure to ensure we were on a fully supported solution, have the capacity to accommodate increasing network traffic volumes and ensure that our network devices are able to have security patches applied to protect against cyber attacks
- Upgraded our cloud connectivity to accommodate the growing number of applications hosted on public cloud infrastructure
- Upgraded server infrastructure to ensure that we are on a fully supported solution, have the capacity to accommodate increasing application demands and ensure that our servers are able to have security patches applied to protect against cyber attacks
- Upgraded our Citrix remote access solution to ensure that we are on a fully supported solution, improve the end user experience and ensure that the solution is able to have security patches applied to protect against cyber attacks
- Upgraded our Netscaler load balancer solution to ensure that we are on a fully supported solution, and ensure that the solution is able to have security patches applied to protect against cyber attacks
- Completed the rollout of Office 365 to all users to enable more users to work remotely without requiring a Citrix or VPN SSL remote access solution
- Continued to rollout a new Windows 10 image, including providing new laptop devices to many users. The new Windows 10 solution includes an "always on" VPN solution to seamlessly connect to simplify the remote working experience.

During the forward planning period for this DAPR, we will continue to upgrade our underlying infrastructure to support our IT environments to maintain capacity, performance and availability to ensure business continuity capability. We will also continue our program of gradually migrating some of our existing on-premise IT infrastructure to the cloud.

18.5 Customer Enablement

The customer engagement incorporates our response to ongoing changes and demands from our customers for greater access and greater choice in their distribution services.

In 2021, we commenced upgrading how our customers access information, saving them time and effort through unifying multiple existing customer portals into a single portal and using artificial intelligence to improve user experience. By the middle of 2022, all our customers will be able to:

- Set and change their communication preferences for planned and unplanned outages
- Make and monitor claims, complaints and compliments
- Add properties to review energy consumption data and use that data to seek out a better retail offer (integrated with existing functionality)
- Seamlessly link out to connections and augmentations requests portals.

Over the life of the DAPR, we will improve the planned outage notification process for our customers, including providing more options around the mediums for communication to better reflect our customer preferences. The improvements will also be reflective of the Essential Services Commission of Victoria's 2020 final decision on the Electricity Distribution Code requirements in relation to planned outages.

18.6 Becoming a more digital network

Distribution networks internationally are on the edge of some of the largest transformations in history driven by changing customer expectations and preferences. These changes are underlined by a desire to move towards low carbon technologies such as roof top solar and electric vehicles and a desire for greater control and independence in their energy usage decisions.

In 2021, we augmented our Distribution Management System to enhance our ability to manage network constraints resulting from solar or wind generators connected to our high voltage network. These changes create opportunities in the future for more flexible connections agreements for future high voltage network customers looking to invest in solar or wind.

In addition, we have established a strategic network analytics capability to complement our SensorIQ investment last year. The investment expands our ability to collect power quality data from smart meters. These enhancements will also allow more dynamic control of voltage across the network, within safe and reliable levels, for customers as well as to maintain system security on high demand days.

We are proactively responding to the energy transformation through building a smarter network able to predict and manage power flows across the low voltage network, ensuring we can operate the network safely and more efficiently, in the face of a low carbon future.

Over the forward planning period we are beginning the following trials:

- Trialling a third party facing interface to enable other market participants access to network assets to participate in markets services such as FCAS and energy arbitrage
- Trialling in 2022 community energy sharing models including network and third party owned batteries as an alternative to network augmentation

- Develop Dynamic Operating Envelope (DOE) methodologies based on AMI and other sensor data to determine how best to implement DOEs and guide investment requirement for ubiquitous integration in the 2026-2030 period

Over the forward planning period a focus will be enhancing asset data models, granularity, quality, and analytics to further improve predictive failure capability.

18.7 Field communication system investments

To facilitate and maintain the protection, control and supervision of the network, we have continued to invest in supervisory control and data acquisition (SCADA) and associated network communication and control equipment. We use SCADA to monitor and control distribution network assets, such as zone substations and feeders. The primary focus of investment through 2021 has been to complete initiatives started in 2020, with additional focus to improve reliability and monitorability of communication assets.

In 2021, the following works have been completed:

- Continued modernisation of the communications network and transitioning protection and SCADA services from mostly aerial legacy copper supervisory cables to optical fibre and, where prudent, wireless enterprise ethernet network and infrastructure
- Completion of evaluation, selection and trial of new 4G technologies in readiness for the shutdown of the Telstra 3G network
- Replacement of 34 narrowband multipoint radio links, in line with the Australian Communications and Media Authority (ACMA) mandated retirement of all 900MHz licenses across our network
- Delivery of improvements to the remote switch (e.g. automatic circuit recloser – ACR, switching cabinets and gas switches) communications availability performance, achieved through selective equipment upgrades, improved commissioning processes and ongoing monitoring
- Introduction of real time communications network monitoring across the CitiPower radio network and the Telstra cellular connected remote switches.
- Continued investment in remote monitoring devices that leverage the new NB-IoT / 5G communication technologies deployed by telecommunication companies. This is proving to be a cost-effective method to remotely determine the condition of assets.

Over the forward planning period for this DAPR, our investment in SCADA will increase, matching the increasing growth and complexity required by the post 2025 NEM reforms and customer expectations and preferences. Our SCADA expenditure will target modernising the communications network and ensuring we retain adequate capability and capacity.

In addition, we will continue to modernise and replace end of life communication systems. This will be to address:

- Technical obsolescence

-
- Better utilise existing high value fixed communication technologies to provide increased capacity and support for a range of technology and business to business bandwidth requirements
 - Rollout of next generation cellular router technology to improved endpoint and back office capabilities and support next generation public wireless public networks
 - Continue to extend communications network monitoring to cover all media used across the business.

We will also review, evaluate and test communication technology options that can deliver improved capabilities and support cost effective delivery of distribution services to our customers.

19 Advanced Metering Infrastructure Benefits

This section discusses our use of advanced metering infrastructure (**AMI**) technology and how information generated by AMI is being used to better support life support customers, guide network planning and demand side response initiatives, and support network reliability initiatives.

19.1 Life support customers

We are using our AMI technology to service and support our vulnerable customers more effectively, allowing us to keep our communities safe.

We are keeping our customers and communities safe through being alerted to life support customers off supply more quickly through our AMI meters across our network. Our systems alert us if the supply to an AMI meter associated with a life support customer fails enabling us to more quickly resolve supply to the customer. This is key to our response planning for customers off-supply and allows us to understand the criticality of the disruption.

Our AMI technology also assists us in rotating load in emergencies. By rotating load, we can share energy among our customers in times of emergency. As such, we can prioritise life-support customers in these cases to ensure their power remains on.

We plan to continue to leverage AMI data and services to develop further benefits for our customers, including life support customers, over the forward planning period. An example of an initiative we are proposing under our Digital Network program which is reliant on our AMI includes more accurate mapping of customers to supplying LV transformers to help keep more life support customers connected during emergency load shedding and provide more accurate communications to customers of planned outages.

19.2 Network planning and demand side response

AMI technology has been critical in allowing us to innovate in the way we operate the network and deliver effective customer service. Visibility of the low voltage (**LV**) network has improved customer outcomes by lowering prices through more efficient network management, improved network safety and reliability outcomes and improved responsiveness to customer needs.

Our AMI meters provide us with the ability to improve safety by identifying neutral faults at customer premises. Our systems alert us if the supply to an AMI meter has a neutral fault enabling us to more quickly resolve it. The system identifies unsafe situations as they develop, so corrective action can be initiated immediately. This is key for maintaining safety for our network and our customers.

Using Victorian AMI specification also allows us to manage voltages and prevent load shedding and blackouts on peak demand days.

Further the Victorian AMI is vital for enabling growth in distributed energy resources (**DER**) such as rooftop solar, batteries and electric vehicles. AMI provides us with the information to manage the network and accommodate the dynamic and less predictable energy flows that result from the increasing uptake of DER technologies by Victorians. We also use our AMI data for more accurate spatial demand forecasting, ensuring we optimise timing of network augmentation. Information from our AMI meters also assist us with detecting of customer with solar connections that are not registered as solar customers and/or are exporting more than they are contracted to export.

Our AMI technology is also an essential input into our Digital Network program which will enable more demand response initiatives through our proposed DER management system as well as enable us to accommodate more solar with the existing network capacity. We plan to continue to leverage AMI data and services to develop new benefits for customers over our DAPR forward planning period. The following are some examples of initiatives we are proposing under our Digital Network program which are reliant on our AMI:

- Promoting electric vehicle uptake – monitoring and optimising EV charging to understand and estimate the impact of increasing demand on the distribution network resulting from EV penetration
- Optimising load control of customer appliances – optimising existing hot water load control and enabling new load control programs (e.g. air conditioners and pool pumps), including through utilising excess solar in the middle of the day
- Enhancing cost reflective incentives – analysing AMI interval data to construct more effective demand management incentives and time-of-use tariffs to reduce peak demand. This would improve overall utilisation of the distribution network, resulting in lower prices
- Detecting electricity theft – identifying sites with bypass connections and reduction of theft, as well as identifying unregistered DER
- Proactively managing asset failures—resulting in fewer fire-starts and avoided replacement expenditure
- Avoiding overblown fuses—improving phase balancing, which will allow greater asset utilisation (and therefore reduce augmentation) as well as avoiding replacement expenditure from blown fuses.

19.3 Network reliability

AMI information is being used to support our network reliability measures. We have shorter outages due to earlier identification of faults and more efficient restoration. This is because AMI meters give us almost instant notification of customers going off supply. We receive immediate notification of outages from the AMI meter which feeds into our outage management systems and automatically schedules and dispatches field crew to restore supply.

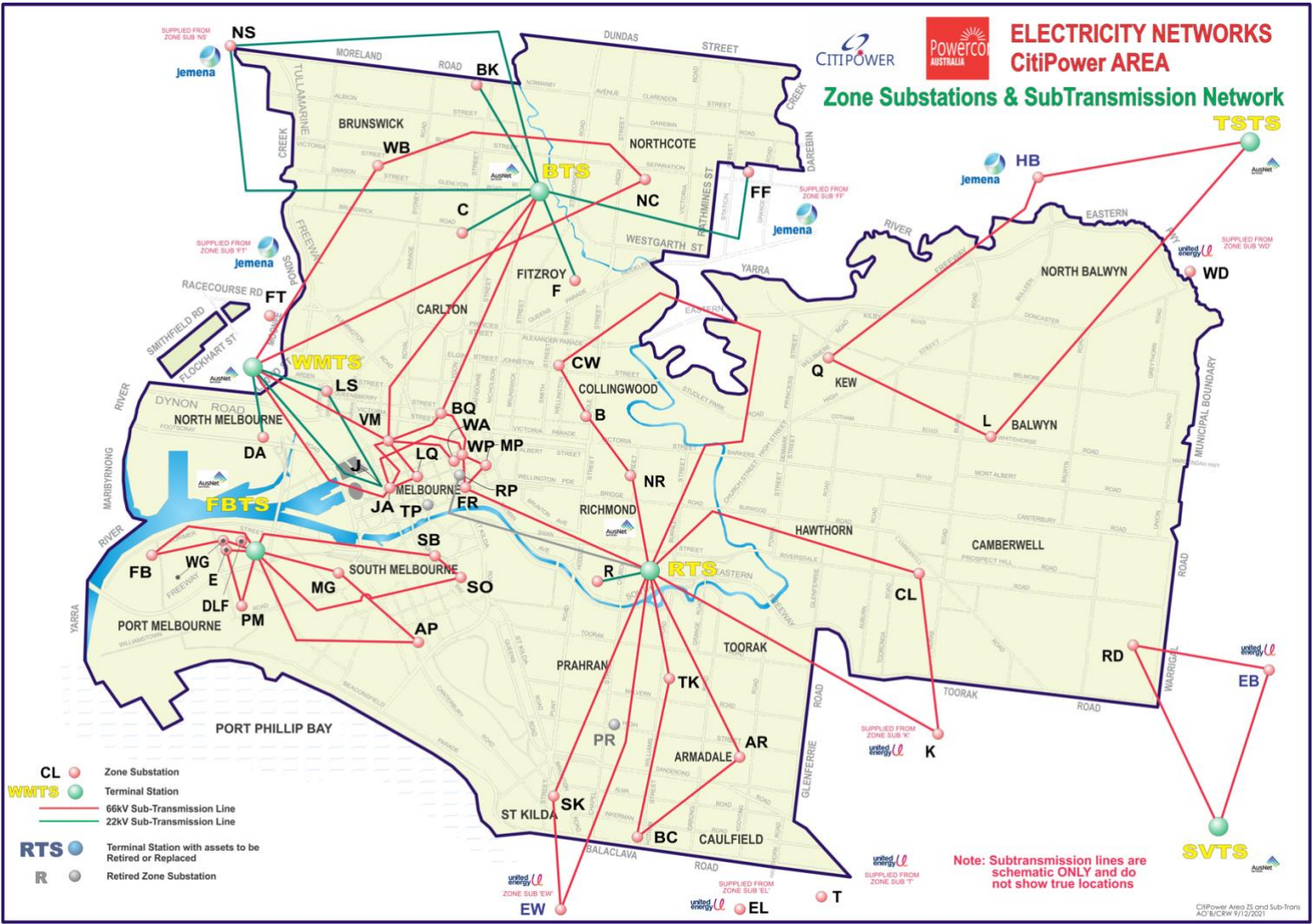
AMI meters also allow us to monitor basic power quality levels at individual customer premises. We have developed query and reporting tools to aggregate the data into meaningful sets of information and provide exception reporting to better manage the quality of supply to customers such as steady-state voltages, voltage sags and swells and phasing information. We have enhanced the AMI architecture to provide an engineering user interface for customer power quality information and to facilitate investigations into poor power quality performance. The interfaces also identify phase unbalance and other power quality performance issues (such as loose connections) to facilitate identifying the most appropriate mitigation solutions.

Our AMI technology also allows for supply capacity control enabling us to more effectively target load shedding to minimise supply impacts.

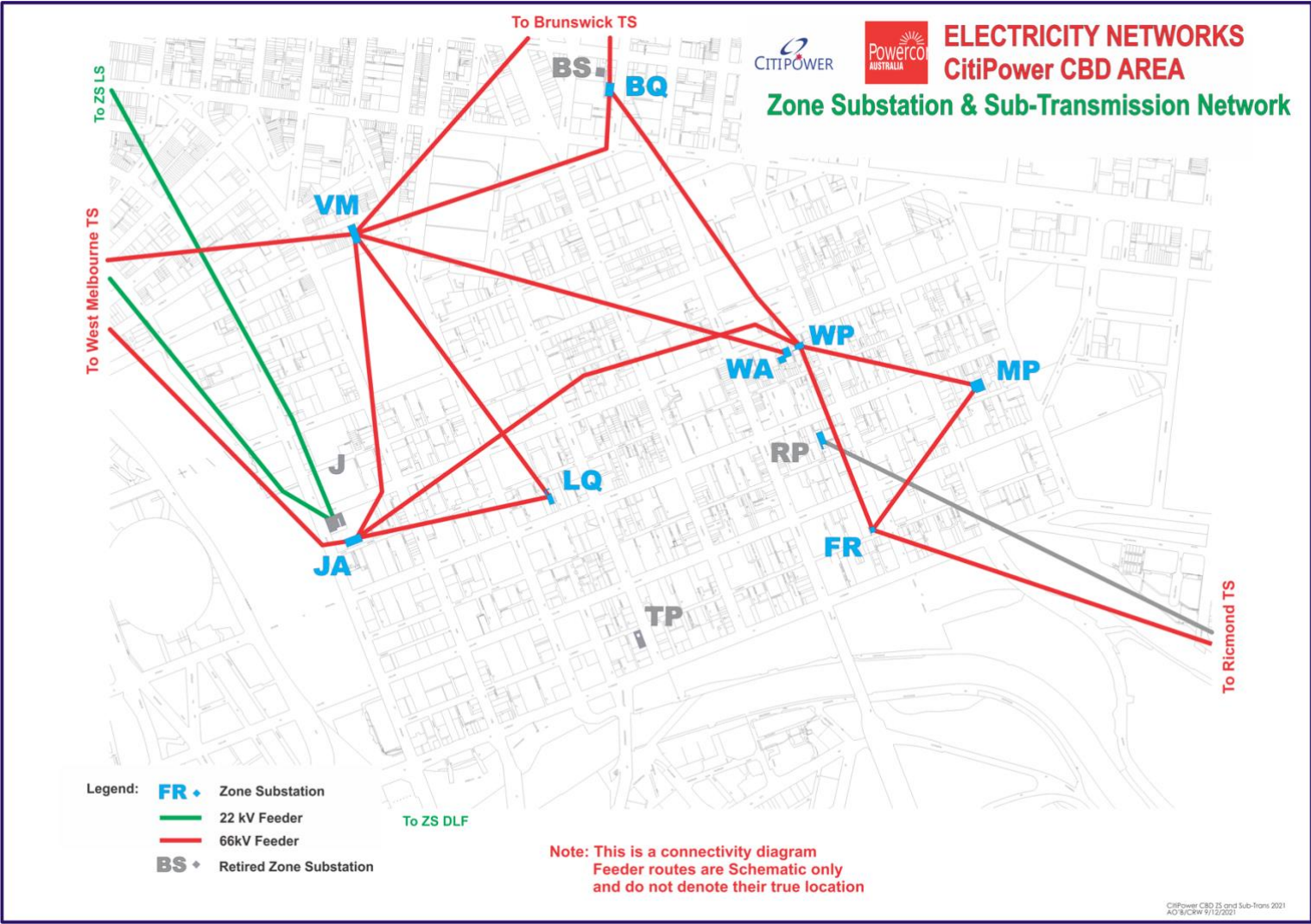
There is also improved quality of information and customer services during outages. We have developed an Interactive Voice Response service and SMS service which automatically advises customers of outages identified in a timely way through the last gasp AMI function. This has contributed to high levels of customer satisfaction with the service received. The quality of supply of information throughout the network is also enabling better network load profiling, identification of safety risks and voltage management.

Appendix A Maps

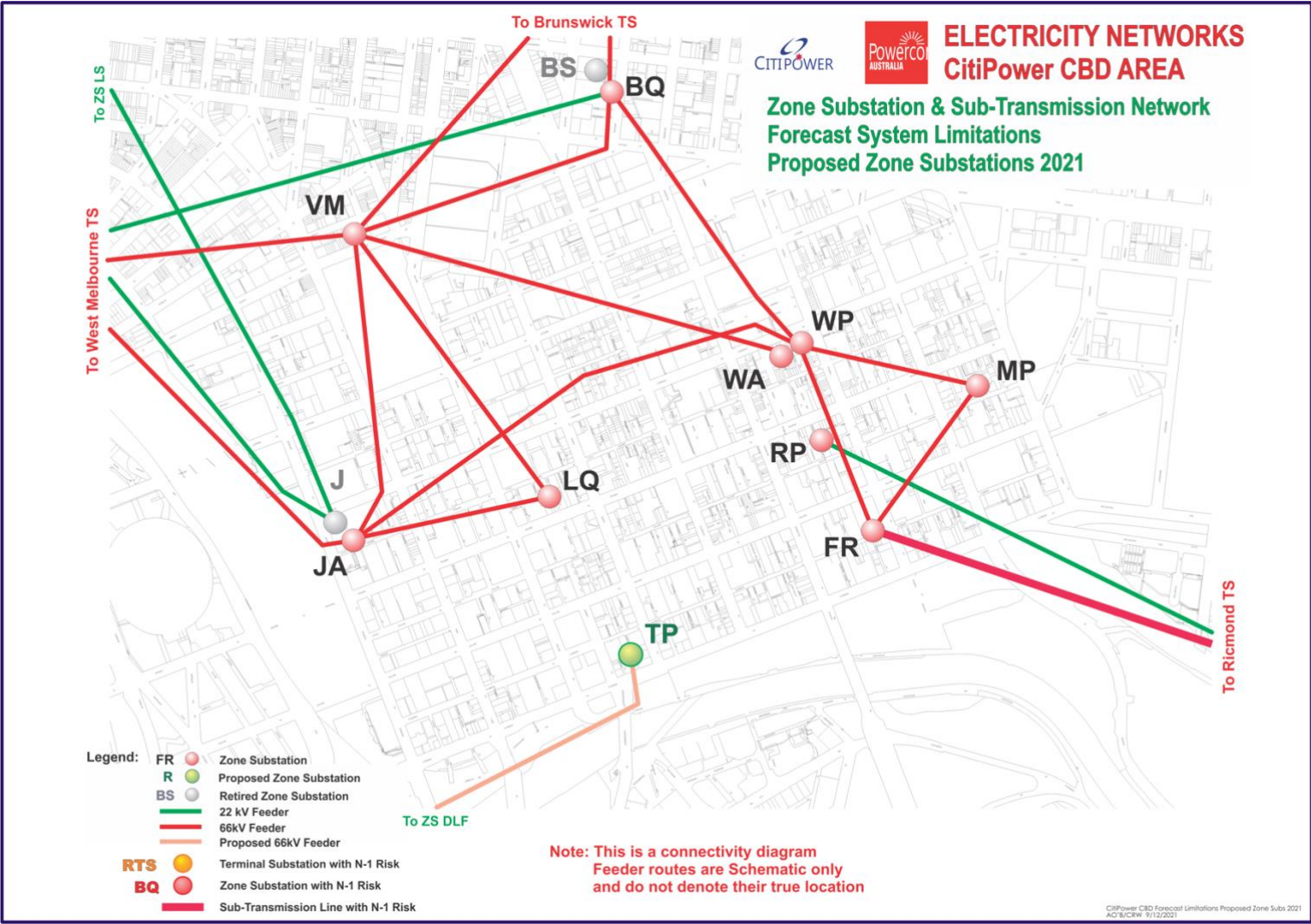
A.1. CitiPower area zone substations and sub-transmission lines



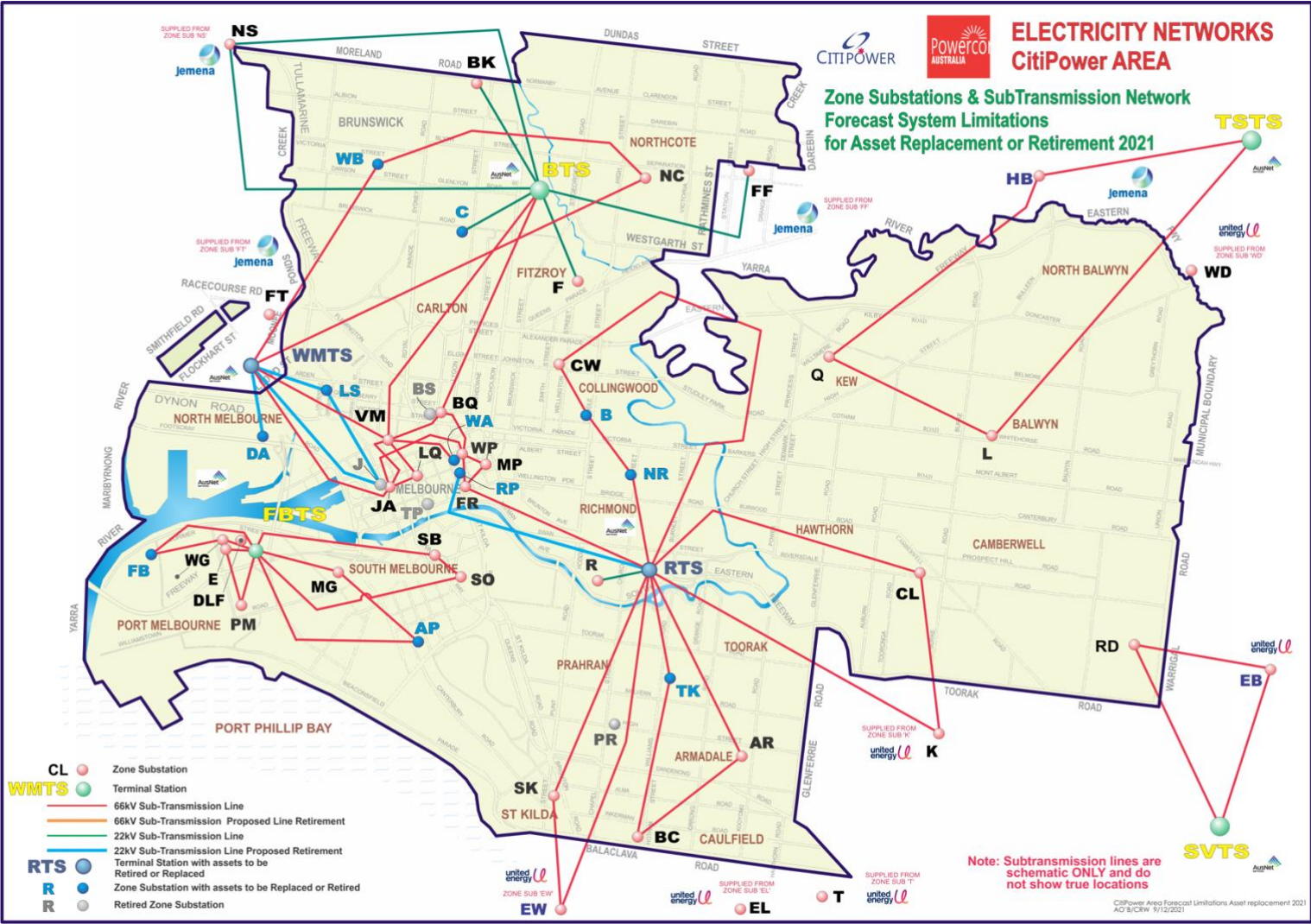
A.2. CBD area zone substations and sub-transmission lines



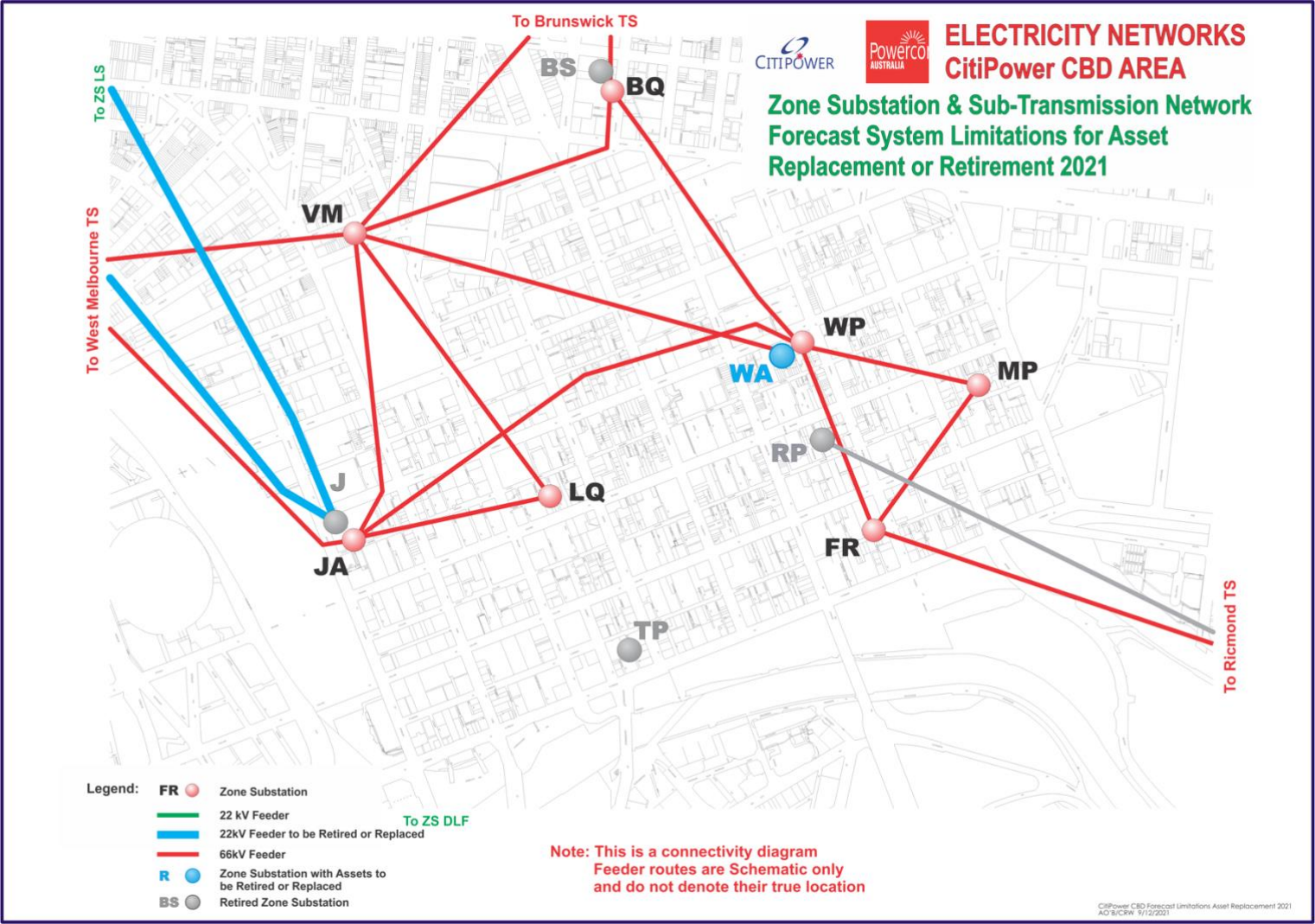
B.2. CBD area map with proposed zone substations



B.3. CitiPower area map with assets to be retired or replaced



B.4. CBD area map with assets to be retired or replaced



Appendix C Glossary and Abbreviations

C.1. Glossary

Common Term	Description
kV	kilo Volt
Amps	Ampere
MW	Mega Watt
MWh	Mega Watt hour
MVA	Mega Volt Ampere
Firm Rating	The cyclic station output capability with an outage of one transformer. Also known as the N-1 Cyclic Rating.
N Cyclic Rating	The station output capacity with all transformers in service. Cyclic ratings assume that the load follows a daily pattern and are calculated using load curves appropriate to the season. Cyclic ratings also take into consideration the thermal inertia of the plant.
N-1 Cyclic Rating	The cyclic station output capability with an outage of one transformer.
Capacity of Line (Amps)	The line current rating which takes into consideration the type of line, conductor materials, allowable insulation temperature, effect of adjacent lines, allowable temperature rise and ambient conditions. It should be noted that CitiPower operates many types of underground cables in its sub-transmission system. The different types of underground cables have varying operating parameters that in turn define their ratings.
MVA above either WCR or SCR	The amount of demand forecast to exceed the Winter Cyclic Rating or the Summer Cyclic Rating.
% Above Capacity	The percentage by which the forecast maximum demand exceeds the N-1 cyclic rating.
Energy at risk	The amount of energy that would not be supplied if a major outage of a transformer or sub-transmission line occurs at the station or sub-transmission loop in that particular year, and no other mitigation action is taken.
Annual hours per year at risk	The number of hours in a year during which the 50 th percentile demand forecast exceeds the zone substation N-1 Cyclic Rating or sub-transmission line rating.

C.2. Zone substation abbreviations

Abbreviation	CitiPower Zone Substation	Abbreviation	CitiPower Zone Substation
AP	Albert Park	MG	Montague
AR	Armada	MP	McIllwraith Place
B	Collingwood	NC	Northcote
BC	Balaclava	NR	North Richmond
BK	Brunswick	PM	Port Melbourne
BQ	Bouverie Queensberry	PR	Prahran
BS	Bouverie St	Q	Kew
C	Brunswick	R	Richmond
CL	Camberwell	RD	Riversdale
CW	Collingwood	RP	Russell Place
DA	Dock Area	SB	Southbank
DLF	Docklands	SK	St Kilda
E	Fishermans Bend	SO	South Melbourne
F	Fitzroy	TK	Toorak
FB	Fisherman's Bend	TP	Tavistock Place
FR	Flinders/Ramsden	VM	Victoria Market
J	Spencer Street	WA	Celestial Avenue
JA	Little Bourke Street	WB	West Brunswick
L	Deepondene	WG	Westgate
LQ	Little Queen	WP	Waratah Place
LS	Laurens Street		

C.3. Terminal station abbreviations

Abbreviation	Terminal Station (AusNet Services Asset)	Abbreviation	Terminal Station (AusNet Services Asset)
BTS	Brunswick	SVTS	Springvale
FBTS	Fisherman's Bend	TSTS	Templestowe
RTS	Richmond	WMTS	West Melbourne

Appendix D Asset Management Documents

CitiPower document references are:

Asset Management Policy: JEQA4UJ443MT-150-27559

Asset Management System Framework: JEQA4UJ443MT-150-27597

Strategic Asset Management Plan: JEQA4UJ443MT-150-27604

Asset Management Strategies subjects – the following table lists the asset management strategies that apply across all asset classes:

Asset management strategy subject	Purpose
Network Operations and Utilisation	Structured approaches to improvements to a range of operational functions which together improve operational performance of the network.
Asset Information and Systems	Asset data and information types, relationships between them and the systems used to manage asset data and information.
Network Performance	Performance improvement programs to meet network reliability and performance requirements over the regulatory period, and an increasingly complex generation and distribution landscape requiring sophisticated technical responses from CP/PAL
Bushfire Mitigation	Structured approaches to prevention of bushfires associated with the design, operation, construction and maintenance of network assets.
Vegetation and Line Clearance (<i>planned for future</i>)	Integration of vegetation and line clearance requirements into the asset management system to align with asset management objectives and ensure ongoing regulatory and statutory compliance.
Connections, Augmentation and Replacement	Improvement programs to manage the connections, augmentation and replacement processes to ensure the network remains capable of distributing a reliable supply of electricity to customers
Maintenance Management	The rationale behind various maintenance management initiatives, projects and plans that together ensure the right maintenance is delivered at the right time and in the right way.
Network Safety	Integration of network safety practices into the asset management system to ensure visibility of regulatory and statutory compliance obligations, and alignment with asset management objectives.
Future Grid	Technologies and smart networks (including batteries, solar and wind generation, decentralised generation, demand management, metering, demand management) and associated impacts on network design, dynamics, monitoring and corresponding changing skill requirements.
Environment and Sustainability (<i>planned for future</i>)	Integration of environment and sustainability requirements into the asset management system to ensure visibility of regulatory and statutory compliance obligations and alignment with asset management objectives.
Asset Management System Performance (<i>planned for future</i>)	Description of the strategies and objectives that CP/PAL use to measure asset management system performance, and ensure optimum asset management system effectiveness, efficiency and continued alignment with the SAMP objectives.
Asset Management System Resources (<i>planned for future</i>)	The assessment, selection, development, procurement or acquisition, deployment and application of human and non-human resources required to develop and implement the CP/PAL asset management system, and implement and monitor the asset management objectives.

Asset Class Strategies – the following table lists the asset class strategy subjects and the asset coverage of each strategy:

Asset class strategy subjects	Asset coverage
Poles and towers	Wood, concrete, and steel poles Steel lattice towers
Pole top structures	Pole top structures including crossarms and insulators HV fuses Surge arresters
Overhead conductors	Bare conductors (aluminium, copper, steel) High voltage aerial bundled cable Low voltage aerial bundled cable Covered conductor
Underground cables	Sub transmission, high voltage and low voltage cables Cable pits Cable pillars Auxiliary services Cascade LV lighting cables
Zone transformers	Zone substation transformers, regulators and autotransformers Transformer bushings Transformer tap changers Transformer water cooling systems
Distribution substation plant miscellaneous	Regulators Capacitors Capacitor balancing units
Public lighting	Luminaires PE cells Brackets
Zone substation plant miscellaneous	Capacitor banks Capacitor bank step switches Reactors Static VAR compensators Instrument transformers Surge diverters Steel work Fire walls Neutral earth resistors (NER) Rapid earth fault current limiter (REFCL) systems Direct current (DC) supply systems Station low voltage (LV) supply systems
Distribution transformers	Pole transformers Kiosk transformers Ground transformers Indoor transformers
SCADA and communications	Optic fibre cable Supervisory cable Digital microwave radio Cellular radio Voice over IP (VoIP) system RTUs
Zone switchgear	Circuit breakers Switchboards Outdoor busses Switches

Asset class strategy subjects	Asset coverage
Protection and control	6.6kV, 11kV, 22kV, 66kV and zone substation protection schemes and relays Line and feeder protection schemes Bus and station protection schemes Transformer protection schemes Cap bank protection schemes
Property and facilities	Zone substation buildings Zone substations leases Non kiosk ground or below ground distribution substations Communications buildings
Metering	AMI network communications AMI single phase direct connected meters AMI three phase direct connected meters AMI LV CT connected three phase meters. Low voltage metering current transformers Pole top high voltage metering VT & CT transformers (CP/PAL owned) Boundary metering HV & EHV Zone substation metering transformers (CP/PAL owned) Legacy type 5 MRIM Meters Legacy type 6 (basic) Meters Timber meter boards (includes CP/PAL owned fuse or facia mounted service protective device (SPD) holders and neutral links)
Distribution switchgear	Circuit breakers Automatic circuit re-closers (ACRs) Switches Ring main units (RMUs)
Service lines	Overhead low voltage service assets Service cable attachment fittings Service protection devices Junction boxes