REFCL ongoing compliance (tranche 1&2)

PAL BUS 6.08–REFCL ongoing compliance – Jan2020 – Public

Regulatory proposal 2021–2026

Powercor

January 2020

Contents

1 Overview

Business	Powercor
Title	REFCL ongoing compliance
Project ID	PAL BUS 6.08 - REFCL ongoing compliance - Jan2020 - Public
Category	Augmentation
Identified need	The identified need arises because: • Each of the nominated 22 zone substations in Powercor's service area must comply with the 'required capacity' specified in the Amended Bushfire Mitigation Regulations; • The works undertaken in relation to tranche one and two zone substations was appropriately scoped to achieve the 'required capacity' by the specified dates, but were not scoped to maintain compliance over the 2021-2026 regulatory period; • As network capacitance continues to increase over time, nine zone substations will become non-compliant with the regulations unless upgrade works are undertaken.
Recommended option	A lowest cost option for each zone substation has been identified by applying a consistent methodology and approach. The option for each zone substation is explained in the appendices to this document. It is recommended that the selected options and the total expenditure in Table 1 is approved.
Proposed start date	2021-2026, most works commence by 2023
Proposed commission date	2021-2026, most works completed by 2024
Supporting documents	1. Cost model - REFCL costs 2. PAL ATT122 – Implementation and optimisation of REFCL systems – Mar2018 - Public

Source: Powercor

The forecast capital expenditure requirements for the 2021–2026 regulatory period, for the preferred ongoing compliance options, are outlined in the table below.

Table 1 Expenditure forecasts for preferred option ($ million, 2021)

Expenditure forecast	2021	2022	2023	2024	2025	2026	Total
Capital expenditure	**0.26**	**6.93**	**41.91**	**11.50**	**-**	**-**	**60.61**

Source: Powercor

2 Background

2.1 REFCL program

Following the Black Saturday bushfires in 2009, the Victorian Government established the Victorian Bushfire Royal Commission (**VBRC**) to consider how bushfires can be better prevented and managed in the future. The VBRC made a number of recommendations to the Victorian Government, including the following:[1]

> *[t]he State amend the Regulations under Victoria's Electricity Safety Act 1998 and otherwise take such steps as may be required to give effect to the following:*
>
> – *the progressive replacement of all SWER (single-wire earth return) power lines in Victoria with aerial bundled cable, underground cabling or other technology that delivers greatly reduced bushfire risk…*
>
> – *the progressive replacement of all 22-kilovolt distribution feeders with aerial bundled cable, underground cabling or other technology that delivers greatly reduced bushfire risk as the feeders reach the end of their engineering lives.*

As part of the Victorian Government's consideration of the recommendations made by the VBRC in its final report, the Powerline Bushfire Safety Taskforce (**PBST**) was established. The PBST was required to investigate new cost efficient and effective technologies and operational practices to reduce catastrophic bushfire risk.

The PBST identified Rapid Earth Fault Current Limiters (**REFCL**s) installed in zone substations as an efficient and effective technology. A REFCL is a network protection device, normally installed in a zone substation, that can reduce the risk of a fallen powerline causing a fire-start. It is capable of detecting when a powerline has fallen to the ground and (almost instantaneously) reduces the voltage on the fallen line. The PBST estimated the installation of REFCLs would reduce the likelihood of multi-phase powerlines starting bushfires by approximately 70 per cent.[2]

On 1 May 2016, the Victorian Government introduced regulations which amended the Electricity Safety (Bushfire Mitigation) Regulations 2013 (**Amended Bushfire Mitigation Regulations**)—to implement the PBST's findings. The regulations specify the timeframes for achieving compliance at Powercor's 22 zone substations. That is, schedule two of the Amended Bushfire Mitigation Regulations assigns a number of 'points' to each of the selected zone substations, as follows:

- at 1 May 2019, the points set out in schedule two of the Amended Bushfire Mitigation Regulations in relation to each zone substation upgraded, when totalled, are not less than 30
- at 1 May 2021, the points set out in schedule two in relation to each zone substation upgraded, when totalled, are not less than 55
- on and from 1 May 2023, in our supply network, each polyphase electric line originating from every zone substation specified in schedule two has the required capacity.

To address these requirements, we structured our REFCL program into structured into three separate tranches, as shown in the figure below.

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1 PAL ATT218: 2009 Victorian Bushfires Royal Commission, *Final Report, Summary*, July 2010, recommendation 27.

2 PAL ATT219: Powerline Bushfire Safety Taskforce, *Final report*, 30 September 2011, p. 5.

Figure 2.1: REFCL program[3]

Tranche one	Tranche two	Tranche three
• Gisborne (GSB)	• Bendigo TS (BETS)	• Corio (CRO)
• Woodend (WND)	• Charlton (CTN)	• Koroit (KRT)
• Camperdown (CDN)	• Bendigo (BGO)	• Stawell (STL)
• Colac (CLC)	• Ballarat South (BAS)	• Waurn Ponds (WPD)
• Castlemaine (CMN)	• Ballarat North (BAN)	• Hamilton (HTN)
• Maryborough (MRO)	• Geelong (GL)	• Ararat (ART)
• Winchelsea (WIN)		• Merbein (MBN)
• Eaglehawk (EHK)		• Terang (TRG)

Source: Powercor

Note: These tranches broadly reflect our contingent project applications to the AER. GSB and WND in tranche one were contained in our regulatory proposal for the 20162020 period as REFCL trial sites. WPD was not included in our third contingent project application and is contained in this regulatory proposal for 20212026 period. The actual deployment programs differ.

2.2 Required capacity

The Amended Bushfire Mitigation Regulations require that each polyphase electric line originating from a selected zone substation has the 'required capacity'. The required capacity is defined as the ability to provide the following, in the event of a phase-to-ground fault on a polyphase electric line:

- to reduce the voltage on the faulted conductor in relation to the station earth when measured at the corresponding zone substation for high impedance faults to 250 volts within 2 seconds
- to reduce the voltage on the faulted conductor in relation to the station earth when measured at the corresponding zone substation for low impedance faults to:
  - 1,900 volts within 85 milliseconds
  - 750 volts within 500 milliseconds
  - 250 volts within 2 seconds
- during diagnostic tests for high impedance faults, to limit:
  - fault current to 0.5 amps or less
  - the thermal energy on the electric line to a maximum I2t value of 0.10.[4]

These requirements can only be met through the use of REFCL technology - specifically, by migrating our existing systems to a resonant earthed network through the installation of a Ground Fault Neutraliser (GFN). A GFN measures the shift in neutral voltage in response to an earth fault and injects additional compensation current to reduce the faulted phase voltage to near zero. This allows the GFN to reduce earth fault current levels at a fault site to near zero.

The number of GFNs required at any zone substation is driven by a range of factors, including total system capacitance. Total system capacitance is itself a function of overhead line and underground cable length (noting the capacitance of underground cable is an order of magnitude more than 40 times that of overhead lines).

3 To manage complexities at Geelong, it was deferred to tranche three and Ararat and Terang were brought forward to tranche two.

4 I^2t means a measure of the thermal energy associated with the current flow, where I is the current flow in amps and t is the duration of current flow in seconds.

2.3 Contingent project applications

We have submitted contingent project applications for each of the three tranches of the REFCL installation program, as follows:

- Our tranche one application was submitted in March 2017 where the scope and cost estimates were based on our REFCL trials at Woodend and Gisborne. At that time, only the REFCL at Gisborne zone substation was in service and only a limited amount of actual information was available for scoping and estimating.
- Our tranche two application was lodged in March 2018. The approach was largely unchanged from tranche one, as no REFCLs had been commissioned prior to the preparation of the application. A number of changes were made to reflect the lessons learnt to date, relating to balancing methodology, cable and current transformer replacements and the use of earth grids.
- Our tranche three application was lodged in August 2019. At the time of that submission, we had commissioned eight tranche one zone substations, and a further three tranche two zone substations were under construction. Naturally, our scoping and cost estimates reflected the lessons learnt to date.

Each of these contingent project applications included a scope of work and expenditure forecasts that enabled us to achieve the 'required capacity' specified in the Amended Bushfire Mitigation Regulations by the specified dates. In accordance with the National Electricity Rules (**Rules**), the Australian Energy Regulator (**AER**) tested whether the proposed expenditure would achieve compliance prudently and efficiently[5].

[5] NER, cl.6.5.7(a)(2) and cl.6.5.7(c)(1)(i) and (ii).

3 Identified need

In section 2, we explained our obligations to comply with the Amended Bushfire Mitigation Regulations in relation to 22 of our zone substations. In accordance with the National Electricity Rules, our contingent project applications for each of the three tranches set out the required works to achieve compliance by the mandated dates. However, the works undertaken in accordance with our contingent project applications are not necessarily sufficient to provide on-going compliance with the Amended Bushfire Mitigation Regulations.

In this business case, therefore, the 'identified need' in relation to a number of tranche one and two zone substations arises from the requirement to ensure that each zone substation continues to meet the ‘required capacity’, as mandated by the Amended Bushfire Mitigation Regulations.

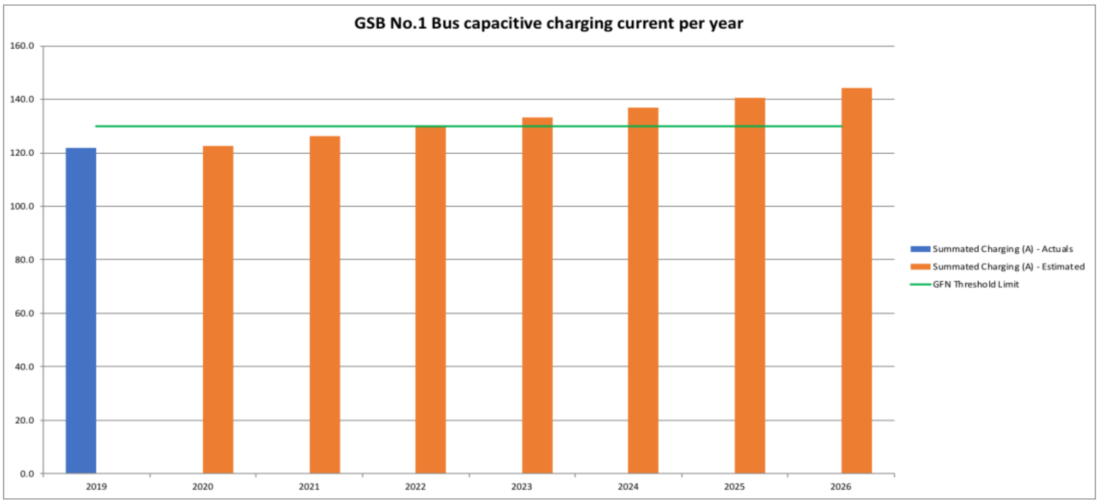
The identified need is driven by the operational capability of the Ground Fault Neutraliser (**GFN**) technology. Our operational experience, together with analysis undertaken by the REFCL technical working group, indicates that a single GFN can support the required performance standards to a maximum total system capacitance of between 81 amps and 108 amps[6]. Our analysis shows that the total system capacitance will increase at tranche one and tranche two zone substations, which will lead to non-compliance during the 2021-26 regulatory period in the absence of upgrade works at the following nine zone substations:

- Ballarat North (**BAN**)
- Ballarat South (**BAS**)
- Bendigo Terminal Station (**BETS**)
- Bendigo (**BGO**)
- Colac (**CLC**)
- Castlemaine (**CMN**)
- Eaglehawk (**EHK**)
- Gisborne (**GSB**)
- Winchelsea (**WIN**).

We have assessed the identified need at each zone substation by comparing the forecast network capacitance against the current capability of the GFNs at each busbar at that zone substation. To illustrate this approach, the figure below shows the data for Gisborne zone substation.

[6] The GFN capability at each zone substation will depend on the specific damping value at that zone substation. A detailed explanation is provided in 'Implementation & Optimisation of Resonant Networks for Victorian REFCL Applications'.

Figure 3.1: Gisborne (GSB) capacitive charging current per year



Source: Powercor

Network capacitance forecasts have been developed to 2026 by applying a growth rate based on the previous five year's average annual growth in network capacitance. One off programs of work, such as the undergrounding of overhead networks as part of the VBRC Powerline Replacement Program, are removed from the growth rate calculations. Any forecast works for these one-off programs are factored into the network capacitance forecasts to reflect the forecast year of completion. The 2019 network capacitance figure was developed by using the actual figure from the results of the 2019 annual compliance testing. For zone substations without GFNs installed, the 2019 network capacitance forecast was developed by using the available actual data for 2019, including all proposed works that have not been completed and adding half the annual forecast growth rate since the actual data only included just under the first half of the 2019 year's actuals. The capacitance forecasts show the value at the end of the relevant year.

This approach to the forecasting of capacitive charging current was presented to the Victorian REFCL Technical Working Group on 9 September 2019. Membership of the REFCL Technical Working Group includes Energy Safe Victoria (**ESV**). The Technical Working Group did not recommend any changes to the methodology, which we regard as a reasonable approach for estimating network capacitance.

4 Options to meet the identified need

As explained in section 3, the identified need is to maintain the 'required capacity' at each tranche one and tranche two zone substations in accordance with the Amended Bushfire Mitigation Regulations. For nine tranche one and two zone substations, the identified need arises because the forecast network capacitance exceeds the current capability of the GFNs at those zone substations. Our objective is to identify the lowest cost option that satisfies our compliance obligations.

To achieve this objective, we developed five high level options, some of which may be used in combination, to address the identified need at each zone substation. The feasibility of each option will depend on the particular characteristics at each zone substation, as set out in the table below.

Table 2: Options and feasibility

	Option	Key issues in determining feasibility
1	**Feeder reconfiguration only**	A key issue is whether the identified need can be addressed through feeder reconfiguration, without incurring the cost of additional GFNs or significant augmentation work. The feasibility of this option depends on the capacity of the existing GFN units. This option is only feasible if there are at least two GFNs at the zone substation.
2	**Adding a new GFN**	The feasibility of this option depends on whether the existing zone substation design is able to accommodate the additional GFN(s) required. This option may necessitate the addition of a new zone substation transformer.
3	**Isolating substations**	It may be possible to reduce the number of GFNs required by electrically isolating underground areas of the 22kV feeders. The feasibility of this option depends on network design (i.e. if there is a significant underground cable with no further overhead conductor downstream), the availability of land and obtaining exemptions from ESV.
4	**Mini zone substation**	The feasibility of this option depends on the availability of land adjacent to the existing zone substation
5	**New zone substation**	The feasibility of this option depends on whether there are existing plans to construct a new zone substation and, if not, whether a suitable site is available.

Source: Powercor

Each of the five options is discussed in further detail below.

- **Option 1 - Feeder reconfiguration only**

  At some zone substations, the forecast growth in capacitance charging may be accommodated by the existing GFN units by reconfiguring the feeders to balance the charging current between the existing GFN units. If feasible, this option will provide the lowest cost solution to address the identified need. In principle, it may also be possible to transfer feeders between REFCL-protected stations. However, for this option to be feasible there must be adequate available capacity at the adjacent zone substation, including sufficient capacity to address the forecast growth in network capacitance.

- **Option 2 - Adding a new GFN**

  If more than one GFN unit is required at a zone substation, meeting the legislated performance standard ("required capacity") requires the feeders being protected by each GFN unit to be electrically isolated. Each segregated group of feeders requires a dedicated 66/22kV power transformer. For system and operational purposes our zone substations are designed for a maximum of three power transformers, the maximum number of GFN units per zone substation is also three.

- **Option 3 - Isolating substations**.

  It may be feasible to use a 22kV isolating substation to electrically isolate an area of the 22kV feeder network that has wholly underground 22kV feeder sections (typically in large residential housing developments). The benefit of this option is that it reduces the number of required GFNs by reducing the capacitive size of the network that the GFN needs to protect.

  However, having areas of the network electrically isolated limits the flexibility in switching the 22kV feeders to restore supply to customers following a fault. As a general rule, the number of isolating substations should be minimised to reduce the loss of operational flexibility that could potentially reduce supply reliability. In addition, spare land close to the underground cable areas will need to be purchased for each isolating substation.

  To operate with isolating substations will require an exemption from the Amended Bushfire Mitigation Regulations, which would be approved by Energy Safe Victoria and the Minister for Energy.

- **Option 4 - Mini zone substation**

  If the zone substation already operates with three GFN units with three power transformers, and additional GFNs must be installed, a potentially cost-effective solution may be to construct an adjacent 'mini zone substation' with a dedicated power transformer, 22kV circuit breakers and additional feeder exits. However, this is a non-standard approach and requires a significant area of spare land, in addition to significant feeder reconfiguration work.

- **Option 5 - New zone substation**

  In most existing zone substations, there is insufficient land to construct a 'mini zone substation'. In these cases, a feasible option may be to bring forward construction of a new zone substation in the area, as already identified in our long-term network plans. In the case where a new zone substation is required, significant feeder reconfigurations will be necessary where selected existing 22kV feeders are redirected to the new zone substation.

For each of the options described above, operating expenditure will be required to conduct annual compliance testing on each 22kV feeder in REFCL protected zone substations. If the preferred solution is a new zone substation or an additional 22kV bus, additional operating expenditure will be required to conduct annual compliance testing for the increased number of feeders. The costs of annual compliance testing has been addressed through a separate step change proposal.

5 Identification of lowest cost, feasible option

Our objective in relation to the ongoing compliance works is to select the lowest cost, feasible option for each of the nine zone substations where the future network capacitance is expected to exceed the current GFN capability. Table 3 describes the factors that will affect the costs of each option and an indicative cost ranking for each option.

Table 3: Cost drivers and cost ranking

	Option	Cost drivers and relative costs	Indicative cost ranking
1	**Feeder reconfiguration only**	This option will be the lowest cost, but it may not address the identified need. As already noted, it is only feasible if there are already two or more GFNs in service at the zone substation. It is appropriate to test the feasibility of this option before considering other options.	Lowest cost
2	**Adding a new GFN**	This option may be the next lowest cost option, depending on the costs of option 3. It also benefits from not requiring an exemption from Energy Safe Victoria. This option should be examined against option 3 if option 1 is not feasible.	Joint 2nd
3	**Isolating substations**	The cost-effectiveness and feasibility of this option will depend on the number of isolating substations required to isolate the underground feeder sections, and the availability and cost of the required land. As noted above, the cost of this option should be examined against option 2 if option 1 is not feasible.	Joint 2nd
4	**Mini zone substation**	This option will be more expensive than options 1 and 2 and possibly more expensive than option 3, therefore it should only be considered if these options are not feasible. The key question for this option is the cost and availability of land, together with the required cost of 22kV feeder reconfiguration work. The cost of this option should be examined against option 5.	Joint 4th
5	**New zone substation**	As noted in relation to option 4, this option will be more expensive than options 1, 2 and 3. If there are already plans to construct a new zone substation, this option may be lower cost than option 4. If not, a key consideration will be the availability and cost of land, together with cost of the required 22kV feeder reconfiguration work.	Joint 4th

Source: Powercor

Table 3 establishes a likely cost ranking of the options, which suggests that the following methodology will identify the lowest cost option, subject to the caveat noted below:

- **Step 1**: Consider the feasibility of Option 1. This option should be adopted if it addresses the identified need ad no further options should be considered.
- **Step 2**: If option 1 is not feasible, select the lowest cost feasible option from options 2 or 3.
- **Step 3**: If options 2 or 3 are not feasible, it will be necessary to consider options 4 and 5. The lowest cost option should be selected.
- **Step 4**: Consider whether a reduced scope of isolating substations (subset of option 3) can be used in combination with options 2, 4 or 5 to deliver a lower total cost solution. If so, this combination of options should be selected. For example, if more than one additional GFN is required in options 2, 4 or 5, this step is

looking at feasible trade-offs to reduce the number of additional GFNs by using a number of isolating substations to reduce the capacitance charging current.

A caveat applies to the application of the above methodology, which is that it may be possible for a new zone substation to address the identified need for two or more zone substations. In applying the methodology set out above, therefore, it is important to consider the relevant supply areas, including plans for new zone substations, to ensure that the optimal solution is identified. A discussion of the relevant considerations in applying the above methodology is provided in the appendices.

Our approach to scoping and costing the selected option is consistent with our contingent project application for tranche three of the REFCL installation program. As such, our approach takes account of the lessons learnt through the implementation of the REFCL program; the actual costs incurred; and the best available cost information in relation to equipment and materials.

6 Summary of expenditure forecasts

The appendices to this document provide the summary cost information for the selection option for each zone substation, applying the methodology set out above. The cost information is expressed in $m, real 2021.

The application of our approach to addressing the identified need for each of the REFCL zone substations is set out in the appendices. It is supported by spreadsheets that detail the scope of works and the cost estimates. The table below provides a summary of the required capital expenditure for each zone substation.

Table 4 Capital expenditure forecasts for the selected options ($ million, 2021)

Zone station	2021	2022	2023	2024	2025	2026	Total
Ballarat West (BAW)[7]	-	3.89	27.15	-	-	-	31.03
Bendigo Terminal Station (BETS)	-	-	-	2.55	-	-	2.55
Bendigo (BGO)	-	-	-	1.23	-	-	1.23
Colac (CLC)	0.26	3.04	-	-	-	-	3.30
Castlemaine (CMN)	-	-	2.79	-	-	-	2.79
Eaglehawk (EHK)	-	-	-	7.73	-	-	7.73
Gisborne (GSB)	-	-	3.26	-	-	-	3.26
Winchelsea (WIN)	-	-	8.71	-	-	-	8.71
Total	**0.26**	**6.93**	**41.91**	**11.50**	**-**	**-**	**60.61**

Source: Powercor

The incremental operating expenditure associated with the proposed capital expenditure will also need to be recovered, noting that a separate step change has been proposed to address the additional compliance testing costs.

7 Ballarat West (**BAW**) provides a joint solution for Ballarat North (**BAN**) and Ballarat South (**BAS**).

A Ballarat North (BAN)

Title	**REFCL ongoing compliance –tranche one and two (BAN)**
Background, including description of zone substation	Ballarat is the largest inland city in Victoria, serving a population base of over 100,000 people. The growth of this region is projected to continue and will require ongoing development of the infrastructure servicing the region. The region is supplied from AusNet Services' Ballarat terminal station (**BATS**), which supplies three Powercor zone substations at 66 kV/22 kV, being Ararat (**ART**), Ballarat North (**BAN**) and Ballarat South (**BAS**). To meet forecast development and growth in the Ballarat region it is planned to establish a new zone substation at Ballarat West (**BAW**). A site adjacent to the proposed Ballarat Link Road between Blind Creek Road and the Skipton Rail trail has been flagged as the potential location of the future BAW zone substation. BAN 66/22 kV zone substation is a fully switched station consisting of three 20/40 MVA transformers and 12 22 kV feeders. It has an N rating of 142.2 MVA(S); N-1 rating of 96.4 MVA(S) and in the 2016/17 summer had a maximum demand of 84MVA. BAN is located in Norman Street adjacent to the old Ballarat 'B' power station building on the edge of the Ballarat Powercor depot and office site. It supplies the Ballarat Central Business District and an area from Clunes to Daylesford in the north and north east, supplying 33,287 customers. Our contingent project application explained that the network capacitance is 292 amps for BAN, requiring three REFCLs to be installed.
Identified need	At BAN, the total zone substation capacitive charging current will exceed the limit at each of the three buses by 2024, due to significant new underground cable growth as load increases. In addition, there are forecast load constraints on BAN 22kV feeders, as a result of developments on the western side of Ballarat, mainly the Ballarat West Employment Zone. The BAN zone substation does not have space for any additional 22kV feeders. The network capacitance forecasts for BAN are set out at the end of this table.
Options not considered to be feasible	**Option 1 - Feeder reconfiguration**. Reconfiguration of feeders is not a feasible option, as this would not address the network capacitance issues. **Option 2 - GFN installation**. Installation of a GFN at the zone substation is not a feasible option, as this cannot be accommodated in the existing zone substation.
Assessment of feasible options	**Option 3 - Isolating substations** This option would require the installation of four new isolating substations (4 x 6MVA) for Ballarat West industrial estate and Miners Rest underground residential development (**URD**). Land purchase would be required. It has been assumed that the four sites would consist of two sections of underground to be isolated. The estimated capital cost of this option is $6.1 million, however the majority of the isolating substations need to be located in built-up urban areas and the availability of land has not been confirmed. **Option 4** - **Mini zone substation**. Whilst there is sufficient space to construct a mini zone substation, the expected costs of this option are $15.7 million. **Option 5 - New zone substation** A new zone substation at BAW is planned for 2030. This option requires the new zone substation to

be brought forward to 2022/2023, and two GFNs installed to address the identified need at both BAN and BAS (which is discussed in Appendix B). This option would require the following works:

- construction of BAW zone substation
- two 25/33MVA transformers; a 66kV loop; four 22kV feeders in a switch room; one capacitor bank; and two GFNs.

The total capital cost of this option is $31.03 million. As this option is capable of addressing the identified REFCL compliance and unserved energy needs at BAN and BAS, it is the most cost-effective option across both substations.

The BAS and BAN demand forecasts alone are indicating the BAW zone substation is justified by 2030, in which case option 5 produces the highest benefit, i.e. construct BAW with two GFNs, and offload part of the BAN and BAS feeders to BAW, ready for service in 2024.

Preferred option and forecast expenditure

For the reasons set out above, the preferred option is Option 5, which is bring forward the construction of the new zone substation at BAW and undertake the associated works to address the identified needs at both BAN and BAS. The forecast capital expenditure for this option is set out below.

Table 5 Expenditure forecasts for preferred option for BAW ($ million, 2021)

Expenditure forecast	2021	2022	2023	2024	2025	2026	Total
Capital expenditure	-	3.89	27.15	-	-	-	31.03

Source: Powercor

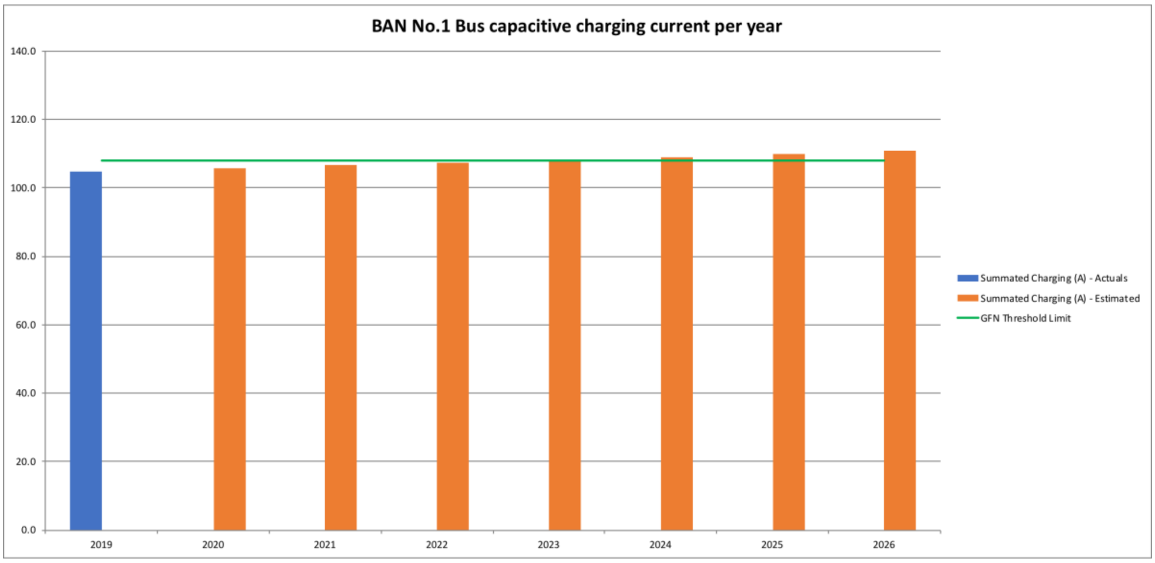
Timing

The works are expected to commence in 2022 and be completed by 31 December 2023.

Forecast network capacitance

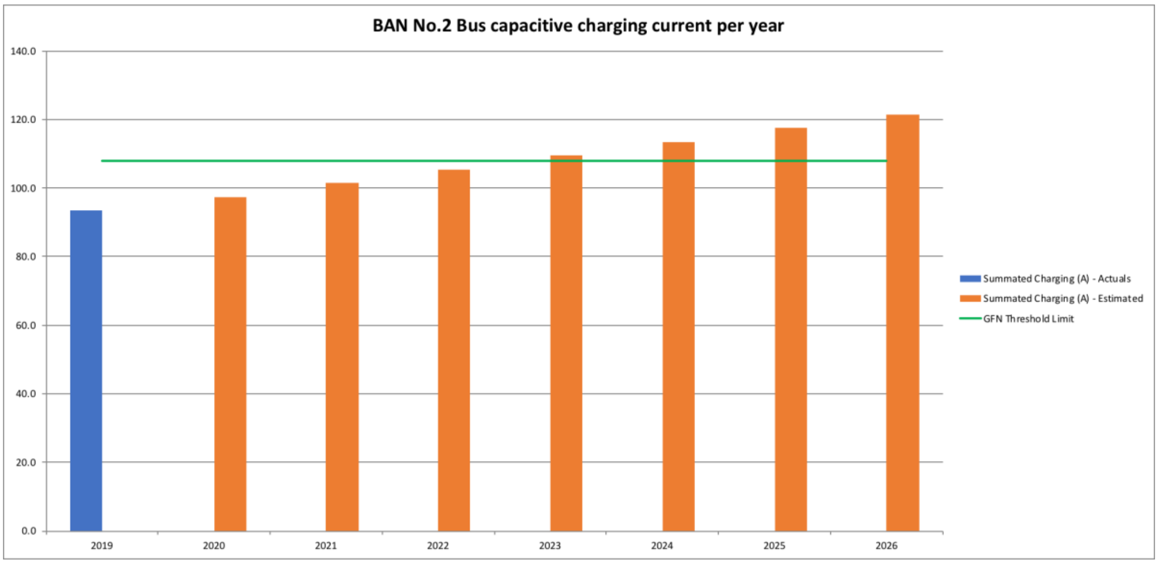
The figures below show the network capacitance forecasts for BAN.

Figure 6.1 BAN bus 1 capacitance forecast



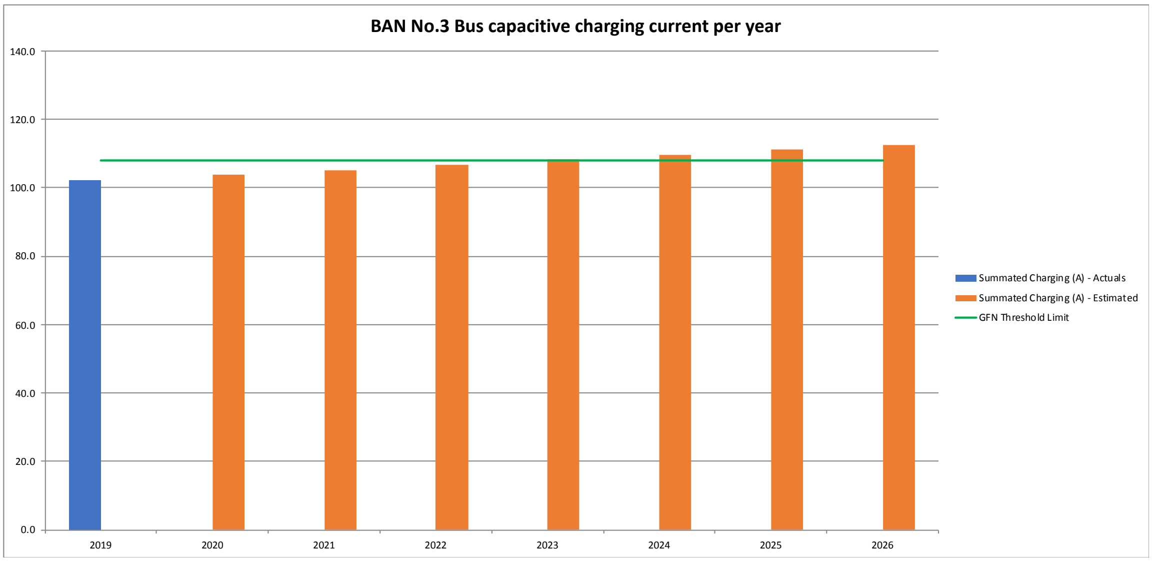
Source: Powercor

Figure 6.2 BAN bus 2 capacitance forecast



Source: Powercor

Figure 6.3 BAN bus 3 capacitance forecast



Source: Powercor

B Ballarat South (BAS)

Title	**REFCL ongoing compliance –tranche one and two (BAS)**
Background, including description of zone substation	As explained in relation to Ballarat North zone substation, the Ballarat region is supplied from AusNet Services' Ballarat terminal station, which supplies three Powercor zone substations at 66 kV/22 kV, being ART, BAN and BAS. To meet forecast development and growth in the Ballarat region it is planned to establish a new zone substation at Ballarat West (**BAW**). BAS 66/22kV zone substation currently consists of two 20/27/33MVA transformers and one 25/33MVA transformer in a fully switched configuration with nine 22kV feeders. It has an N rating of 114 MVA(S); N-1 rating of 76 MVA(S) and in the 2016/17 summer had a maximum demand of 71 MVA. BAS is located on Sutton Street in the southern Ballarat suburb of Redan and supplies the southern part of Ballarat as well as area south and west of Ballarat such as Skipton and Beaufort. A total of 36,948 customers are supplied from this zone substation. Our contingent project application explained that the network capacitance is 280 amps for BAS, requiring three GFNs to be installed.
Identified need	At BAS, the substation capacitive charging current will exceed the Bus No.2 and Bus No.3 limit by 2024, as a result of significant new underground cable growth. There are also forecast load constraints at BAS, with its N-1 rating expected to be exceeded early in the 2021-26 regulatory period as a result of developments on the western side of Ballarat, mainly URDs and commercial developments as part of the Ballarat West Growth Corridor. The network capacitance forecasts for BAS are set out at the end of this table.
Options not considered feasible	**Option 1 - Feeder reconfiguration**. Reconfiguration of feeders is not a feasible option, as this would not address the network capacitance issues. **Option 2 - GFN installation**. Installation of a GFN at the zone substation is not a feasible option, as this cannot be accommodated in the existing zone substation.
Assessment of feasible options	**Option 3 - Isolating substations** This option would require the installation of eight new isolating substations (8 x 6MVA) – Lucas URD area, Delacombe URD area. Land purchase would be required. It has been assumed that the eight sites are to consist of four sections of underground to be isolated in a looped arrangement. The estimated capital cost of this option is $12.2 million, however the majority of the isolating substations need to be located in built-up urban areas and the availability of land has not been confirmed. **Option 4** - **Mini zone substation**. Whilst there is space available at the site due to it creating a non-standard zone substation, and using space earmarked for a future 66kV ring bus for the new BAW zone substation. A fifth transformer would be required by 2026 if a BAS solution was solely used. A new indoor switchboard would also be required, as there would only be one spare 22kV feeder exit available once the GFN is installed to address the identified need. In addition, the capital cost of a mini zone substation is estimated to be $23.5 million, which is not a cost-effective option. **Option 5 - New zone substation** As noted in relation to BAN, the planned zone substation at BAW would provide the most cost-

effective solution to address the identified need at both BAS and BAN. This option would require the following works:

- construction of BAW zone substation
- two 25/33MVA transformers; a 66kV loop; four 22kV feeders in a switch room; one capacitor bank; and two GFNs.

The total capital cost of this option is $31.03 million. As this option is capable of addressing the identified REFCL compliance and unserved energy needs at BAN and BAS, it is the most cost-effective option across both substations.

The option of employing isolating substations at both BAN and BAS is not a credible long term option. The BAS and BAN demand forecasts alone are indicating the BAW zone substation is justified by 2030, in which case option 5 produces the highest benefit, ie construct BAW with two GFNs, and offload part of the BAN and BAS feeders to BAW, ready for service in 2024.

Preferred option and forecast expenditure

For the reasons set out above, the preferred option is option 5, which is to bring forward the construction of the new zone substation at BAW and undertake the associated works to address the identified needs at both BAS and BAN.

For information purposes, the forecast capital expenditure for this option is reproduced below, noting that this information has already been presented in relation to BAN.

Table 6 Expenditure forecasts for preferred option for BAS ($ million, 2021)

Expenditure forecast	2021	2022	2023	2024	2025	2026	Total
Capital expenditure	-	3.89	27.15	-	-	-	31.03

Source: Powercor

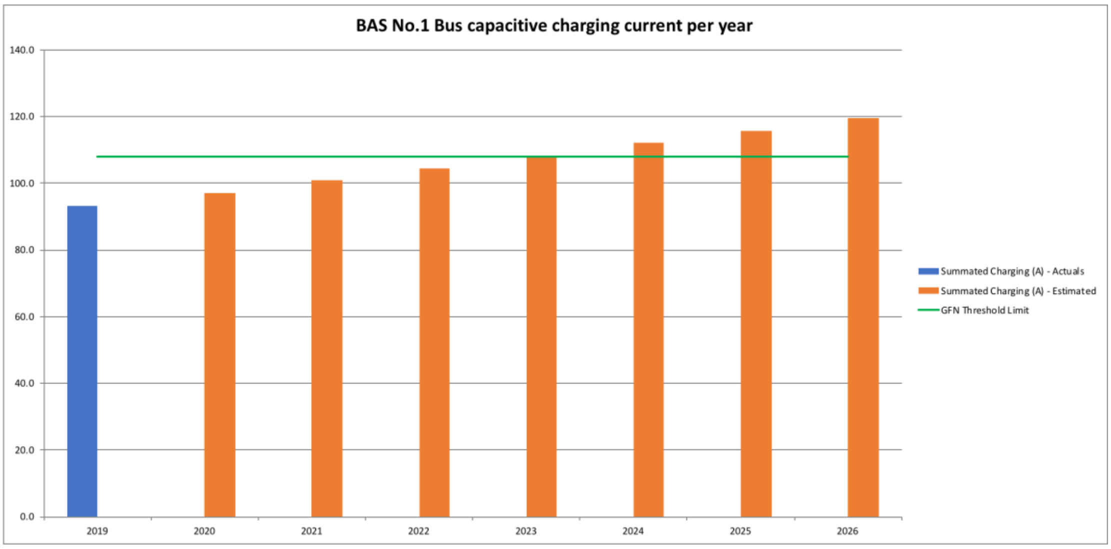
Timing

The works are expected to commence in 2022 and be completed by 31 December 2023.

Forecast network capacitance

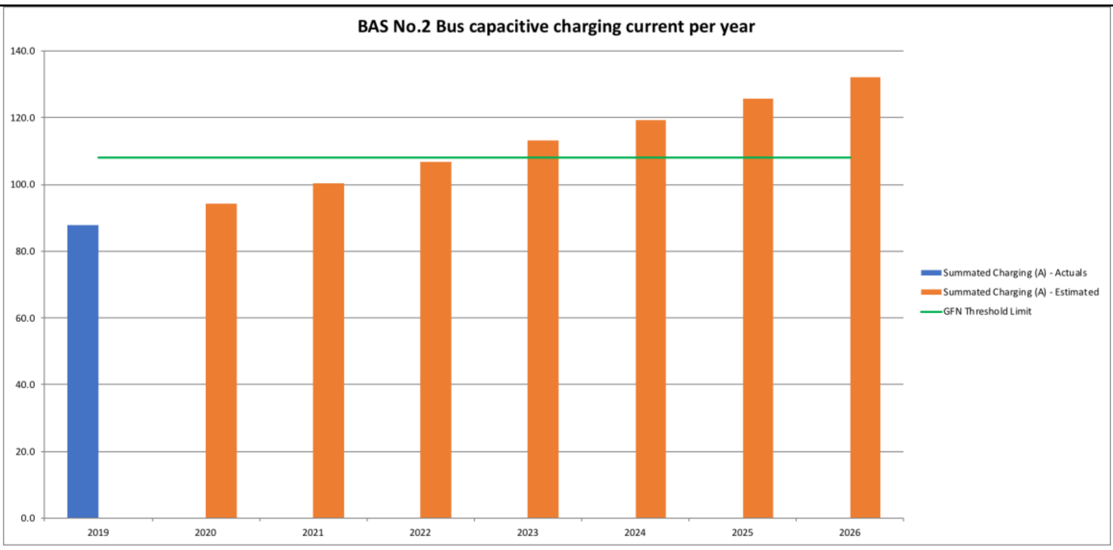
The figures below show the network capacitance forecasts for BAS.

Figure 6.4 BAS bus 1 capacitance forecast



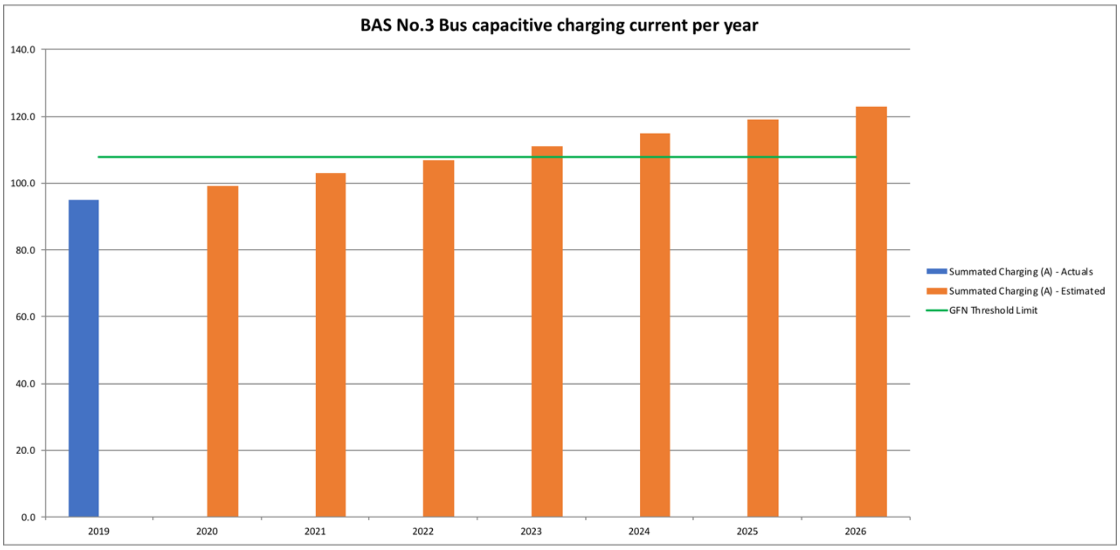
Source: Powercor

Figure 6.5 BAS bus 2 capacitance forecast



Source: Powercor

Figure 6.6 BAS bus 3 capacitance forecast



Source: Powercor

C Bendigo Terminal Station (BETS)

<table>
<tr><td>Title</td><td>REFCL ongoing compliance –tranche one and two (BETS)</td></tr>
<tr><td>Background, including description of zone substation</td><td>BETS is situated on the Victorian 220kV network between Shepparton and Ballarat terminal stations and is supplied via single circuit 220kV lines. The terminal station is also an integral part of the outer 220kV transmission ring supplying Kerang, Red Cliffs and Horsham terminal stations via a 220kV line from Bendigo to Kerang.

BETS has one 150MVA and one 125MVA 220/66 kV transformers supplying the 66kV network and two 75 MVA 220/22 kV transformers supplying the Powercor 22kV network. The 22kV bus is separated into two banks of transformers with a normally open bus-tie CB for fault level containment. BETS is a summer peaking station with an underlying load growth in the order of 2.8% per annum.

Two GFNs will be installed at BETS as part of the tranche two REFCL installation program.</td></tr>
<tr><td>Identified need</td><td>At BETS, the capacitive charging current on bus No.4 is expected to exceed the limit of the GFN in 2025. In order to maintain compliance with the Amended Bushfire Mitigation Regulations, we must address the network capacitance issues before 2025.

The network capacitance forecasts for BETS are set out at the end of this table.</td></tr>
<tr><td>Options not considered feasible</td><td>As explained below, a number of options were considered feasible but were found to be uneconomic.</td></tr>
<tr><td>Assessment of feasible options</td><td>The preferred option is a combination of:
• Option 1 - feeder reconfiguration and
• Option 3 - isolating substations

This combination of options addresses the network capacitance issue on bus No.4 by utilising one isolating substation to reduce the capacitance charging current and rearranging some feeder sections between busses to optimally balance the charging current between the 2 busses.

A zone substation solution was considered, but discounted as the cost of a new terminal station transformer would be excessive, and it was concluded that the Least Cost Technically Acceptable (LCTA) option is an isolating substation option.

Stage 1 (in 2021) – feeder rearrangement x 1

Stage 2 (in 2024) – install one new isolating substation (1 x 6MVA).

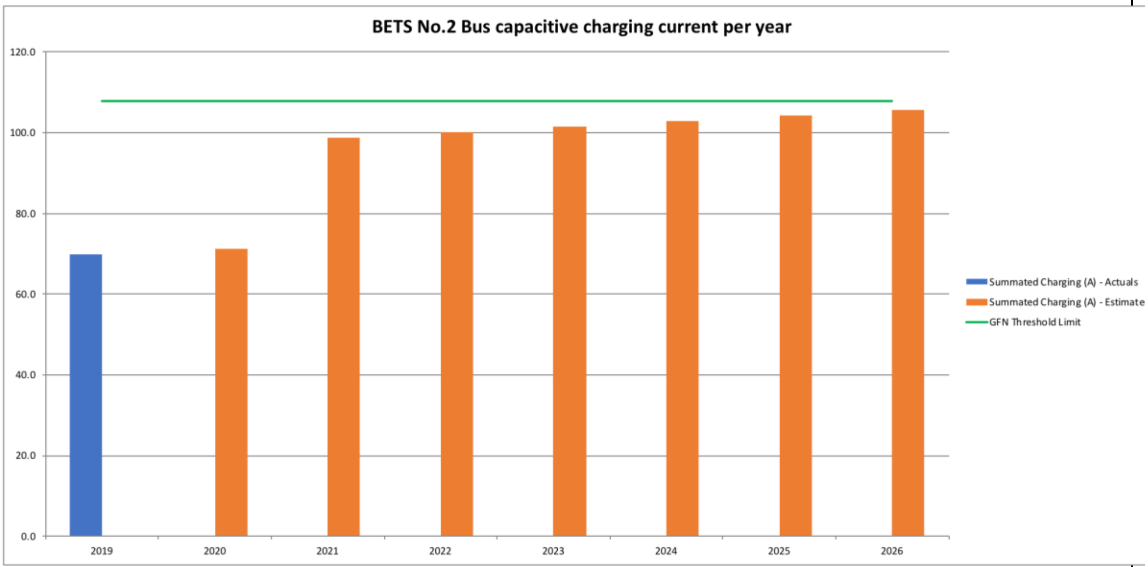
New transformer option was also discounted as it would be a terminal station transformer and it is historically costly for such works to be completed.</td></tr>
<tr><td>Preferred option and forecast expenditure</td><td>The forecast capital expenditure for the preferred option, being a combination of Options 1 and 3, is set out below. The incremental operating expenditure will also need to be recovered.

Table 7 Expenditure forecasts for preferred option for BETS ($ million, 2021)

<table><tr><th>Expenditure forecast</th><th>2021</th><th>2022</th><th>2023</th><th>2024</th><th>2025</th><th>2026</th><th>Total</th></tr><tr><td>Capital expenditure</td><td>-</td><td>-</td><td>-</td><td>2.55</td><td>-</td><td>-</td><td>2.55</td></tr></table></td></tr>
</table>

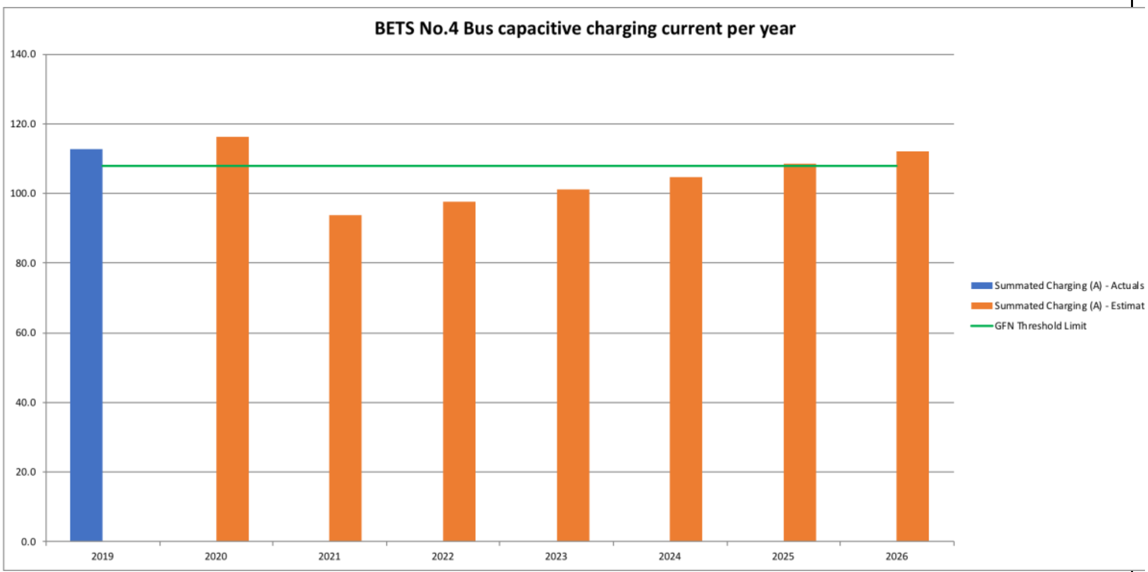
<table>
<tr><td></td><td>Source: Powercor</td></tr>
<tr><td>Timing</td><td>The works are expected to commence in 2021 and be completed by 31 December 2024.</td></tr>
<tr><td>Forecast network capacitance</td><td>
The figures below show the network capacitance forecasts for BETS.

Figure 6.7 BETS bus 2 capacitance forecast



Source: Powercor

Figure 6.8 BETS bus 4 capacitance forecast



Source: Powercor
</td></tr>
</table>

D Bendigo (BGO)

<table>
<tr><td>Title</td><td>REFCL ongoing compliance –tranche one and two (BGO)</td></tr>
<tr><td>Background, including description of zone substation</td><td>The BGO zone substation is served by sub-transmission lines from the Bendigo terminal station. It supplies the City of Bendigo and the area to the east. The BGO 66/22 kV zone substation is a fully switched station consisting of two 20/27/33 MVA transformers and seven 22 kV feeders. It has an N rating of 77 MVA(S), N-1 rating of 38.5 MVA(S). Load transfers away to EHK and BETS 22kV are available in the event of a loss of a transformer at BGO.

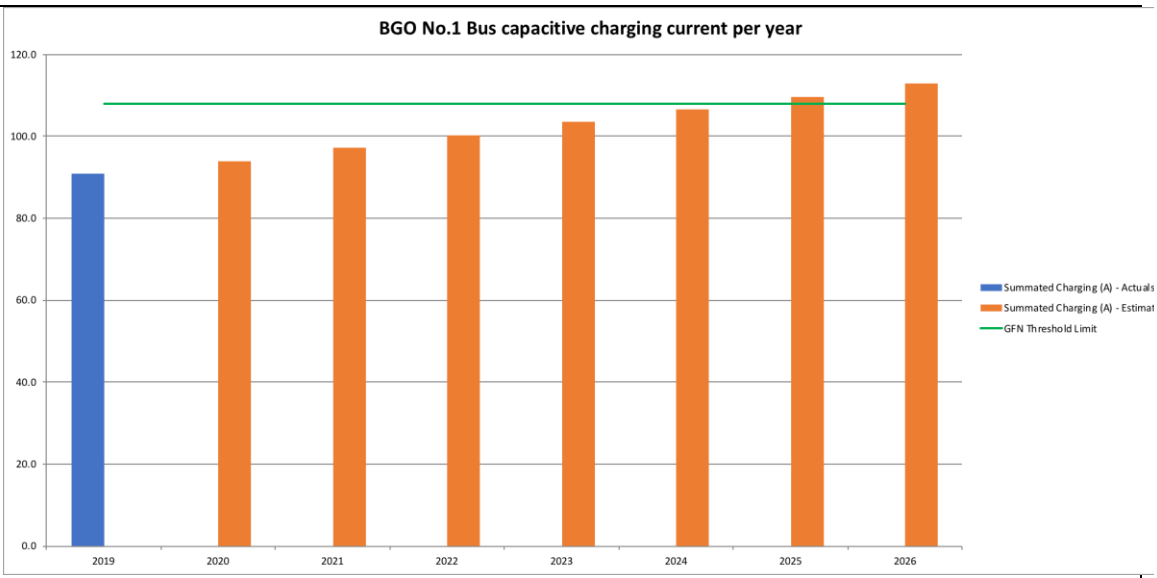
Two GFNs will be installed at BGO as part of the tranche two REFCL installation program.</td></tr>
<tr><td>Identified need</td><td>At BGO, the 22kV Bus No.1 capacitive charging current limit will be exceeded in 2025. As previously noted, we must ensure that we continue to comply with the Amended Bushfire Mitigation Regulations.

The network capacitance forecasts for BGO are set out at the end of this table.</td></tr>
<tr><td>Options not considered feasible</td><td>The identified need can be addressed by feeder reconfiguration, which is the lowest cost option. As explained in section 5 of this paper, it is not necessary to consider other options if the identified need can be addressed by feeder reconfiguration.</td></tr>
<tr><td>Preferred option and forecast expenditure</td><td>The preferred option is to address the charging current on Bus No.1 by rearranging two 22kV feeders between Bus No.1 and Bus No.2. A distribution transfer may be required to keep bus load under the transformer rating.

The forecast capital expenditure for the preferred option is set out below.

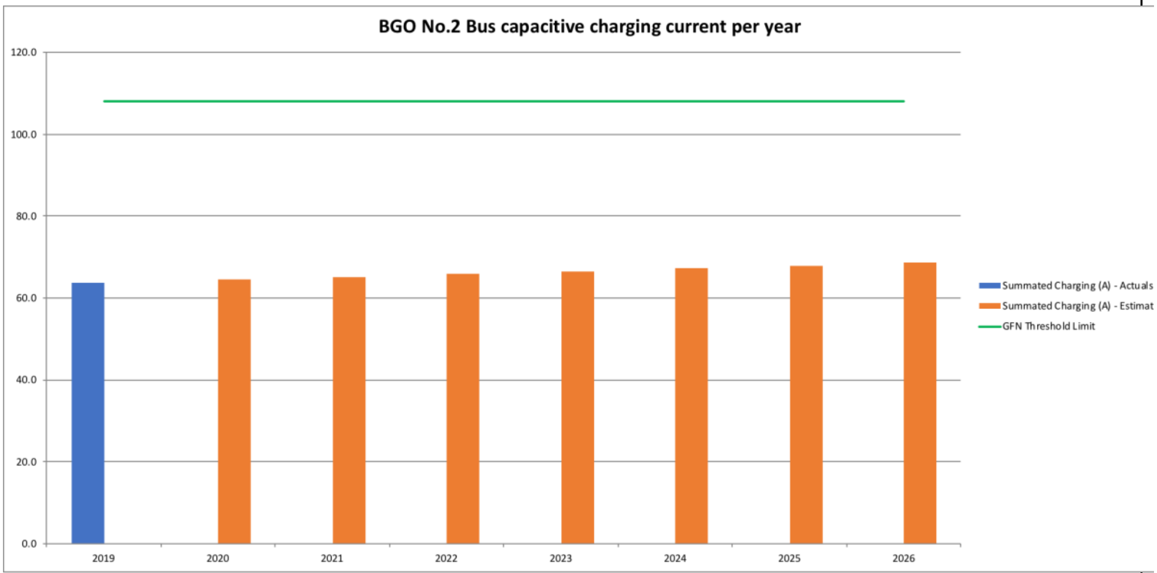
Table 8 Expenditure forecasts for preferred option for BGO ($ million, 2021)
<table>
<tr><th>Expenditure forecast</th><th>2021</th><th>2022</th><th>2023</th><th>2024</th><th>2025</th><th>2026</th><th>Total</th></tr>
<tr><td>Capital expenditure</td><td>-</td><td>-</td><td>-</td><td>1.23</td><td>-</td><td>-</td><td>1.23</td></tr>
</table>
Source: Powercor</td></tr>
<tr><td>Timing</td><td>The required work must be undertaken in 2024 in order to address the identified need.</td></tr>
<tr><td>Forecast network capacitance</td><td>The figures below show the network capacitance forecasts for BGO.

Figure 6.9 BGO bus 1 capacitance forecast</td></tr>
</table>



Source: Powercor

Figure 6.10 BGO bus 2 capacitance forecast



Source: Powercor

E Colac (CLC)

Title	**REFCL ongoing compliance –tranche one and two (CLC)**
Background, including description of zone substation	The CLC zone substation is located on the corner of Forest Street and the Colac – Forrest Road and largely supplies the Colac township, north to Beeac, east to Lorne, and south to Apollo Bay. A total of 16,787 customers are supplied from this zone substation. CLC 66/22 kV zone substation is a fully switched station consisting of two 25/33 MVA transformers and a 10/13 MVA transformer and seven 22 kV feeders. Two GFNs have been installed at CLC, as part of the works required in relation to tranche one of the REFCL program.
Identified need	At CLC, the total zone substation capacitive charging current will exceed the limit at both Bus No. 1 and No.2 by 2022. We must ensure that we maintain compliance with the Amended Bushfire Mitigation Regulations by addressing the network capacitance issues. The network capacitance forecasts for CLC are set out at the end of this table.
Options not considered feasible	**Option 1 - feeder reconfiguration**. This option cannot address the network capacitance issue as there is insufficient total GFN capability to address the forecast growth in network capacitance. **Option 3 - isolating substations**. An isolating substation solution is not feasible as there are two large underground sections (5.6km on CLC006, and 3.84km on CLC013) which are not at the end of the line or on spurs. As a consequence, this option would only be technically acceptable if a significant amount of overhead line (tens of kms) were converted to underground cable, and an isolating substation installed.
Assessment of feasible options	**Option 2 - GFN installation.** This option is feasible at CLC because there is an available transformer without a REFCL. We therefore propose to install a new REFCL at CLC, including a neutral bus, and other REFCL associated equipment. In addition to addressing the network capacitance issue, we proposed to swap feeder CLC003 with CLC006 to obtain more charging current on Bus 2. The estimated capital cost of this option is $3.3 million. As explained in section 5 of this paper, as option 2 is feasible and isolating substations cannot address the network capacitance issues at CLC, a mini zone substation (option 4) or a new zone substation (option 5) are not cost effective options. For example, the cost of option 4 is estimated to be $7.9 million.
Preferred option and forecast expenditure	For the reasons set out above, the preferred option is to undertake option 2, which will require the following works: • install a third GFN at CLC, including a neutral bus, and other REFCL associated equipment • swap feeder CLC003 with CLC006. The forecast capital expenditure for this option is set out below. Table 9 Capital expenditure forecasts for preferred option for CLC ($ million, 20121) Expenditure forecast: 2021 / 2022 / 2023 / 2024 / 2025 / 2026 / Total Capital expenditure: 0.26 / 3.04 / - / - / - / - / 3.30 Source: Powercor

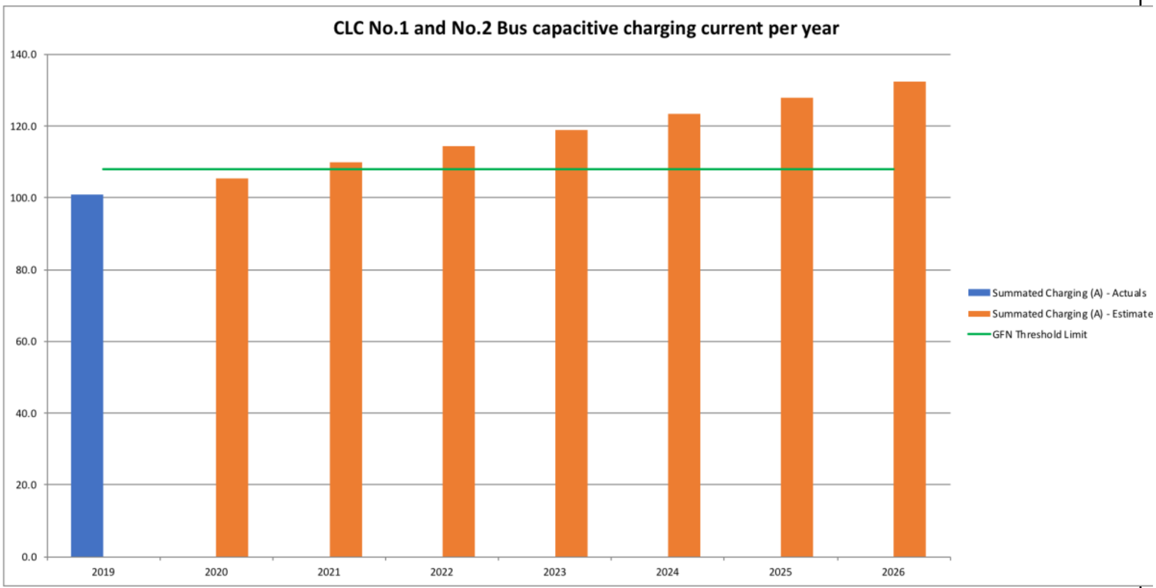
Table 9 Capital expenditure forecasts for preferred option for CLC ($ million, 20121)

Expenditure forecast	2021	2022	2023	2024	2025	2026	Total
Capital expenditure	0.26	3.04	-	-	-	-	3.30

Source: Powercor

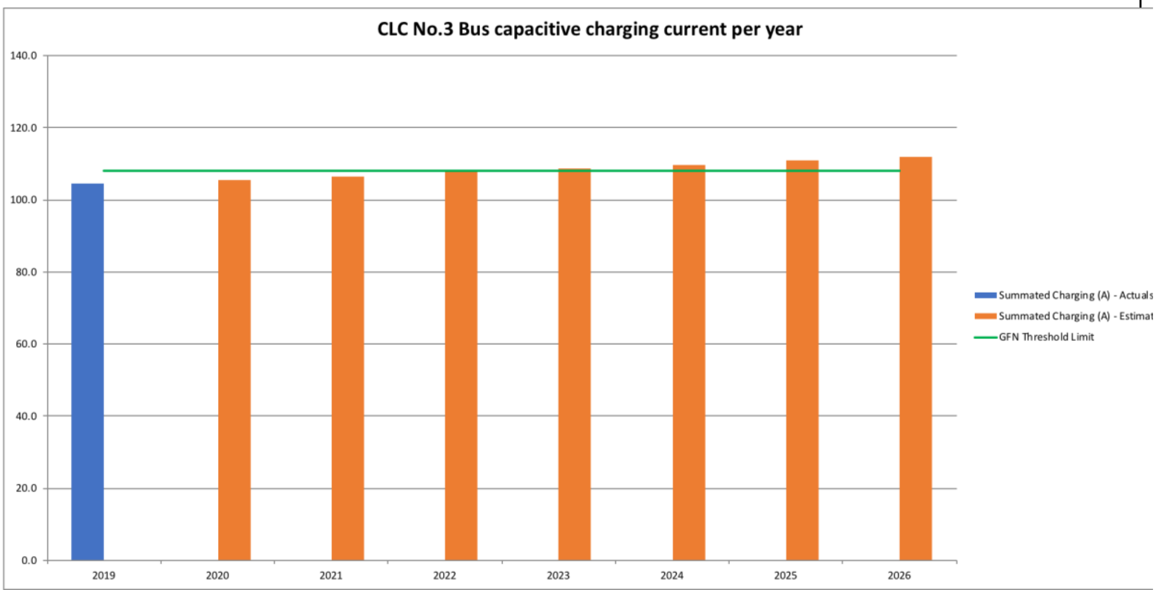
<table>
<tr><td>Timing</td><td>The works are expected to commence in 2021 and be completed by 31 December 2022.</td></tr>
<tr><td>Forecast network capacitance</td><td>The figures below show the network capacitance forecasts for CLC.

Figure 6.11 CLC bus 1 and 2 capacitance forecast



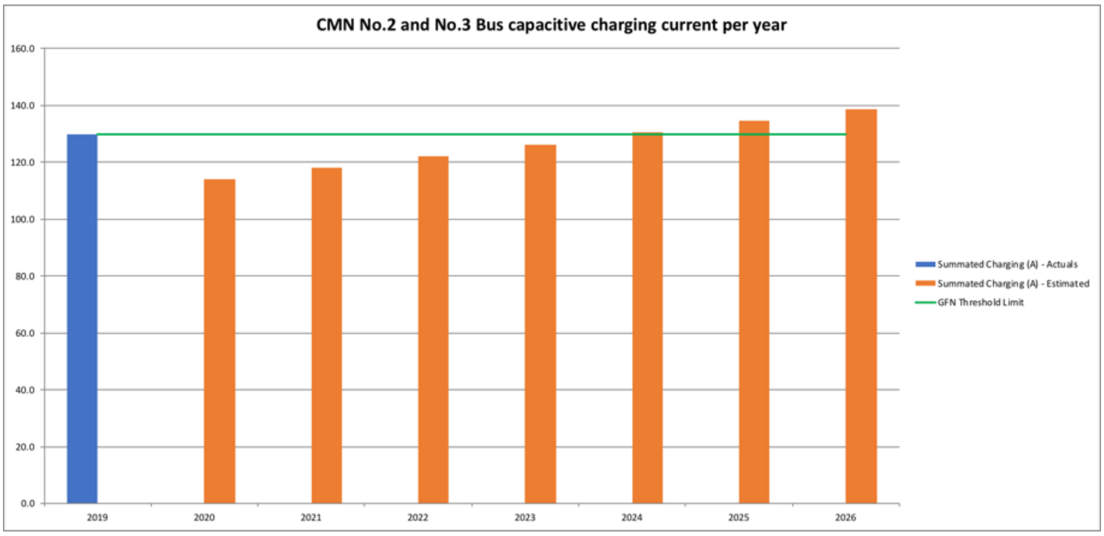
Source: Powercor

Figure 6.12 CLC bus 3 capacitance forecast



Source: Powercor</td></tr>
</table>

F Castlemaine (CMN)

Title	**REFCL ongoing compliance –tranche one and two (CMN)**
Background, including description of zone substation	CMN zone substation is located on the corner of Elizabeth Street and Johnstone Street, Castlemaine. The substation has two 25/33MVA transformers in a fully switched configuration, meaning that the installation includes 22kV transformer and bus tie circuit breakers. One GFN has been installed at CMN as part of the tranche one REFCL program.
Identified need	The capacitive charging current at CMN will exceed the limit at Bus No.2 and No.3 by 2024. We must ensure that we maintain compliance with the Amended Bushfire Mitigation Regulations by addressing the network capacitance issues. **Figure 6.13 CMN bus 1 and 2 capacitance forecast**  Source: Powercor Note: the forecast reduction in the network capacitance in 2020 assumes that a transfer can be utilised to defer the need for augmentation.
Options not considered feasible	**Option 1 - feeder reconfiguration**. This option is not feasible because there is only one GFN installed at CMN and therefore feeder reconfiguration cannot address the network capacitance issue. We also considered transferring a large enough section of network to Maryborough, but found this option not to be feasible given the forecast growth in network capacitance. **Option 3 - isolating substations**. This option is not feasible because there are no large sections of underground cables that would be suitable for this solution.
Assessment of feasible options	**Option 2 - GFN installation.** This option is feasible at CMN because there is an available transformer without a REFCL. The estimated capital cost of this option is $2.79 million. As explained in section 5 of this paper, as Option 2 is feasible and isolating substations cannot address the network capacitance issues at CMN, a mini zone substation (Option 4) or a new zone substation (Option 5) are not cost effective options. We therefore propose to install a new REFCL at CMN.

<table>
<tr><td>Preferred option and forecast expenditure</td><td>For the reasons set out above, the preferred option is to install a third GFN at CMN, as per option 2.

The forecast capital expenditure for this option is set out below.

Table 10 Expenditure forecasts for preferred option for CMN ($ million, 2021)

<table><tr><th>Expenditure forecast</th><th>2021</th><th>2022</th><th>2023</th><th>2024</th><th>2025</th><th>2026</th><th>Total</th></tr><tr><td>Capital expenditure</td><td>-</td><td>-</td><td>2.79</td><td>-</td><td>-</td><td>-</td><td>2.79</td></tr></table>
Source: Powercor</td></tr>
<tr><td>Timing</td><td>The works are expected to commence in 2023 and be completed by 31 December 2023.</td></tr>
</table>

G Eaglehawk (EHK)

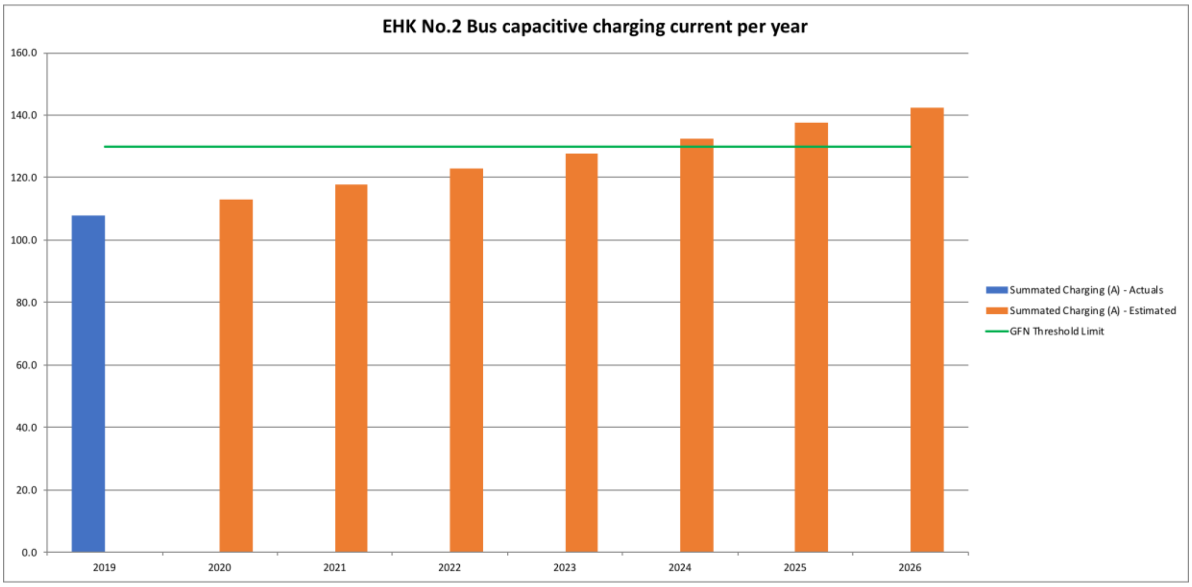
Title	**REFCL ongoing compliance –tranche one and two (EHK)**
Background, including description of zone substation	EHK zone substation is served by sub-transmission lines from the Bendigo terminal station. It supplies Eaglehawk, Bridgewater, Inglewood, the northern part of Bendigo and the surrounding areas north of Bendigo. EHK 66/22 kV zone substation is a fully switched station consisting of two 20/27 MVA transformers and eight 22 kV feeders. It has an N rating of 72.8 MVA(S), N-1 rating of 36.4 MVA(S). Installation of a new 25/33 MVA third transformer at EHK zone substation is planned to address the load-at-risk constraint. Two GFNs have been installed as part of the tranche one REFCL installation program.
Identified need	The total zone substation capacitive charging current at EHK will exceed the limit at Bus No.2 and Bus No.3 in 2024. We must ensure that we maintain compliance with the Amended Bushfire Mitigation Regulations by addressing the network capacitance issues. There are also load constraints at the EHK zone substation as load exceeds the N-1 rating, as explained in our Distribution Annual Planning Report. It is anticipated that in the absence of the REFCL requirements, the third transformer would be justified, on the value of expected unserved energy, before the end of the 2021–26 regulatory period. The network capacitance forecasts for EHK are set out at the end of this table.
Options not considered feasible	**Option 1 - Feeder reconfiguration**. This option cannot address the network capacitance issue as there is insufficient GFN capability to address the forecast growth in network capacitance.
Assessment of feasible options	**Option 2 - GFN installation.** This option involves installing a new transformer and GFN. A new transformer is required to address the load at risk at EHK, which reduces the incremental costs of installing a GFN. The cost of this option is $7.73 million. **Option 3 - Isolating substations**. This option would involve installing three 6MVA isolating substations) two on Bus No.2 and one on Bus No.3 to reduce the network capacitance on each bus. The cost of this option is $5.38 million. However this option does not address the expected unserved energy. As explained in section 5 of this paper, option 2 is expected to be a lower cost option than a mini zone substation (option 4) or a new zone substation (option 5). For EHK, as a new transformer is required at EHK to address the load issues, options 4 and 5 are not cost effective options to address the network capacitance issues.
Preferred option and forecast expenditure	For the reasons set out above, option 2 is preferred as it will address the network capacitance growth and the expected unserved energy issues at EHK at the lowest net cost. This option involves installing a GFN on the No.1 transformer, including a neutral bus, and undertaking the following works: • install a new 25/33 MVA No.1 transformer at EHK • install two new feeder CBs, a No.1-2 bus tie CB, and 22kV Tx No.1 CB • install a new No.1 22kV Bus VT • two feeder rearrangements - transfer a bus 1 feeder and a bus 2 feeder to bus 1. The forecast capital expenditure for this option is set out below. Table 11 Expenditure forecasts for preferred option for EHK ($ million, 2021)

Expenditure forecast	2021	2022	2023	2024	2025	2026	Total
Capital expenditure	-	-	-	7.73	-	-	7.73

Source: Powercor

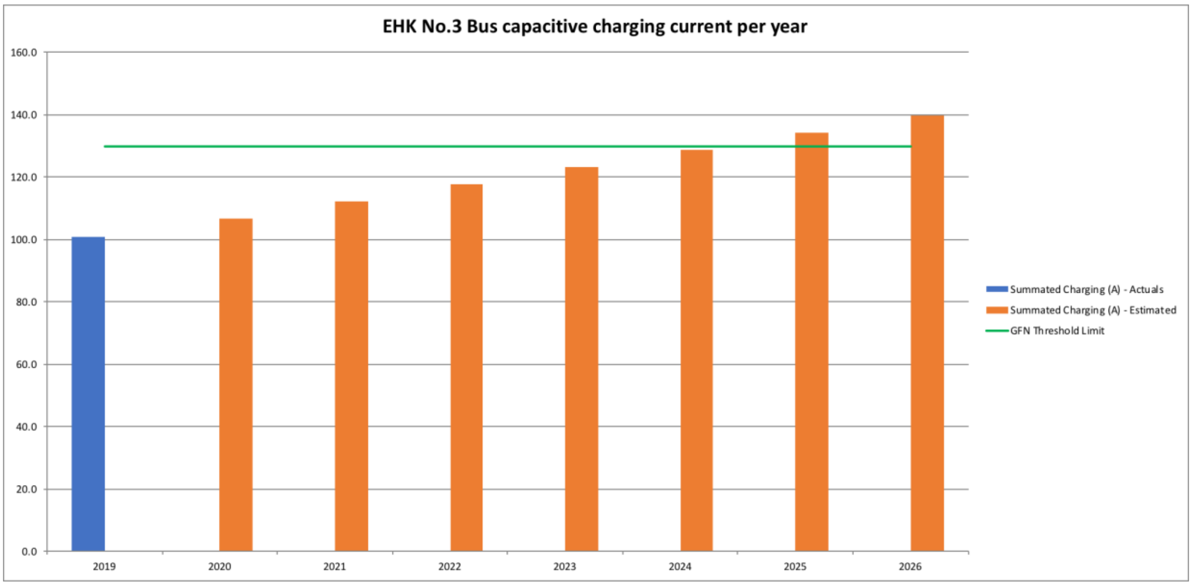
Timing	The works are expected to commence in 2024 and be completed by 31 December 2024.
Forecast network capacitance	The figures below show the network capacitance forecasts for EHK.

Figure 6.14 EHK bus 2 capacitance forecast



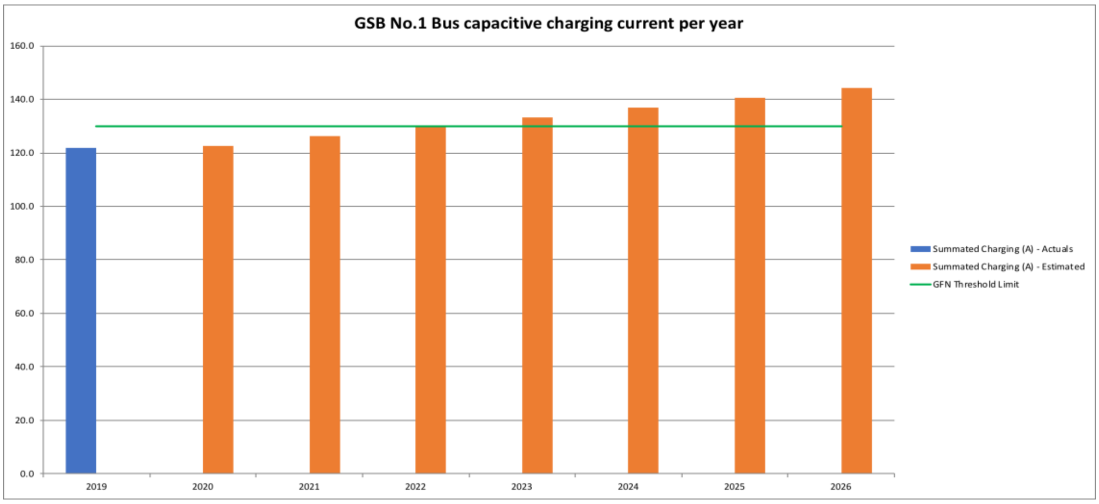
Source: Powercor

Figure 6.15 EHK bus 3 capacitance forecast



Source: Powercor

H Gisborne (GSB)

Title	**REFCL ongoing compliance –tranche one and two (GSB)**
Background, including description of zone substation	GSB zone substation is located on Macedon-Woodend Road just north of the intersection with Mount Macedon Road. It supplies the towns of Gisborne, Macedon, Riddells Creek and Bullengarook. GSB 66/22 kV zone substation is served by sub-transmission lines from the Keilor terminal station (**KTS**) via Sunbury (**SBY**) zone substation. It currently consists of two 25/33 MVA transformers in a fully switched configuration, and four 22 kV distribution feeders. A GFN was installed at GSB as part of the tranche one installation program.
Identified need	The total zone substation capacitive charging current at GSB will exceed the station limit in 2023. We must ensure that we maintain compliance with the Amended Bushfire Mitigation Regulations by addressing the network capacitance issues. Figure 6.16 GSB bus 1 capacitance forecast  Source: Powercor
Options not considered feasible	**Option 1 - feeder reconfiguration**. This option is not feasible because there is only one GFN installed at GSB and therefore feeder reconfiguration cannot address the network capacitance issue. **Option 3 - isolating substations**. This option is not considered feasible because there are no sufficiently sized sections of underground cable.
Assessment of feasible options	**Option 2 - GFN installation.** This option is feasible at GSB because there is an available transformer without a REFCL. The estimated capital cost of this option is $3.26 million. As explained in section 5 of this paper, as option 2 is feasible and isolating substations cannot address the network capacitance issues at GSB, a mini zone substation (option 4) or a new zone substation (option 5) are not cost effective options. We therefore propose to install an additional REFCL at GSB.

<table>
<tr><td>Preferred Option and forecast expenditure</td><td>
For the reasons set out above, the preferred option to address the network capacitance issues at GSB is to undertake option 2, which will require the following works:

install an additional REFCL at GSB, including a neutral bus, and other REFCL associated equipment
2 x feeder rearrangements (transfer two feeders to Bus 2).

The forecast capital expenditure for this option is set out below.
Table 12 Expenditure forecasts for preferred option for GSB ($ million, 2021)
<table>
<tr><th>Expenditure forecast</th><th>2021</th><th>2022</th><th>2023</th><th>2024</th><th>2025</th><th>2026</th><th>Total</th></tr>
<tr><td>Capital expenditure</td><td>-</td><td>-</td><td>3.26</td><td>-</td><td>-</td><td>-</td><td>3.26</td></tr>
</table>
Source: Powercor
</td></tr>
<tr><td>Timing</td><td>The works are expected to commence in 2023 and be completed by 31 December 2023.</td></tr>
</table>

I Winchelsea (WIN)

Title	**REFCL ongoing compliance –tranche one and two (WIN)**
Background, including description of zone substation	The WIN zone substation is located on the corner of Princes Highway and Gladman Street on the east side of the Winchelsea township. It supplies the township of Winchelsea, Inverleigh, Moriac, Deans Marsh and surrounding areas. WIN is served by two sub-transmission lines from the Geelong Terminal Station (**GTS**) and Colac (**CLC**) zone substation. It consists of a 10/13 MVA and 5/7 MVA 66 kV/22 kV transformer supplying a 22 kV bus and three distribution feeders controlled by Automatic Circuit Reclosers. Two GFNs were installed as part of the required works in tranche one of the REFCL installation program.
Identified need	At WIN, the total zone substation capacitive charging current will exceed the limit at Bus No.2 in 2024. We must ensure that we maintain compliance with the Amended Bushfire Mitigation Regulations by addressing the network capacitance issues. The network capacitance forecasts for WIN are presented at the end of this table.
Options not considered feasible	**Option 1 - feeder reconfiguration**. This option cannot address the network capacitance issue as there is insufficient GFN capability to address the forecast growth in network capacitance.
Assessment of feasible options	**Option 2 - GFN installation.** This option involves installing a new transformer and GFN. The cost of this option is $8.71 million. **Option 3 - isolating substations**. An isolating substation solution is not cost effective due to the lack of any one large purely underground section on WIN. An isolating substation solution would require a significant length of overhead line to be converted to underground cable, which means that this option is not cost effective. As explained in section 5 of this paper, as option 2 is feasible and isolating substations cannot address the network capacitance issues at WIN, a mini zone substation (option 4) or a new zone substation (option 5) are not cost effective options. We therefore propose to install a new REFCL and transformer at WIN.
Preferred option and forecast expenditure	For the reasons set out above, the preferred option to address the network capacitance issues at WIN is to undertake option 2, which will require the following works: • install a new 25/33 MVA No.3 transformer at WIN (66kV yard may need to be rearranged) • install a new No.3 22kV switchboard (4 CBs: 1x feeder, 1x Tx CB, 1x 2-3 bus tie) • install a new No.3 22kV Bus VT • install a new REFCL on the No.3 transformer, including a neutral bus, and other REFCL associated equipment • install a new feeder on 3rd bus to split up WIN022. The forecast capital expenditure for this option is set out below.

Table 13 Expenditure forecasts for preferred option for WIN ($ million, 2021)

Expenditure forecast	2021	2022	2023	2024	2025	2026	Total
Capital expenditure	-	-	8.71	-	-	-	8.71

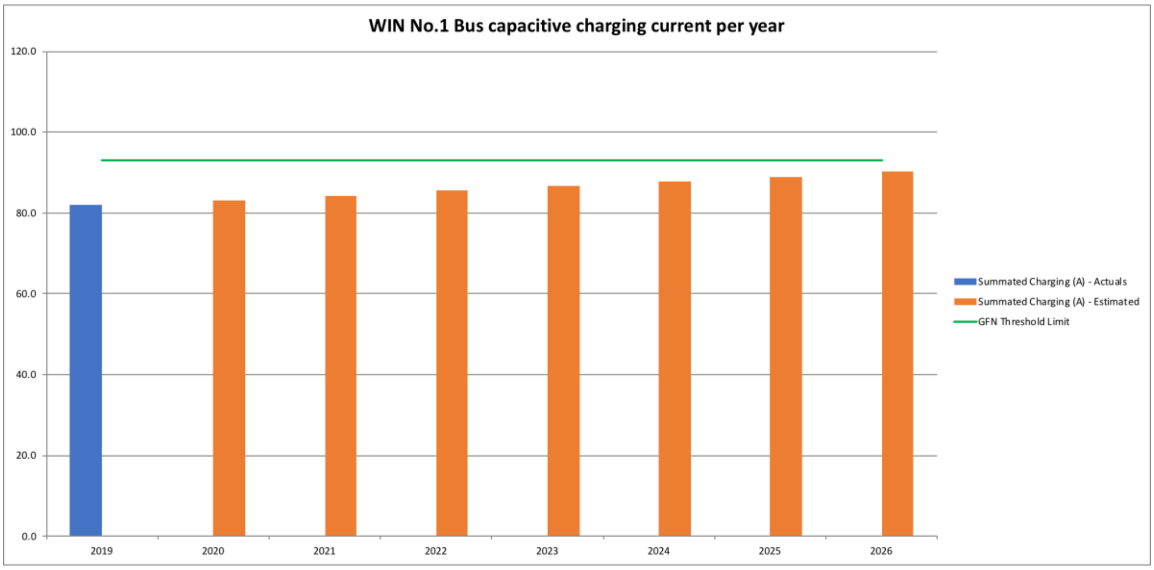
Source: Powercor

Timing	The works are expected to commence in 2023 and be completed by 31 December 2023.

Forecast network capacitance

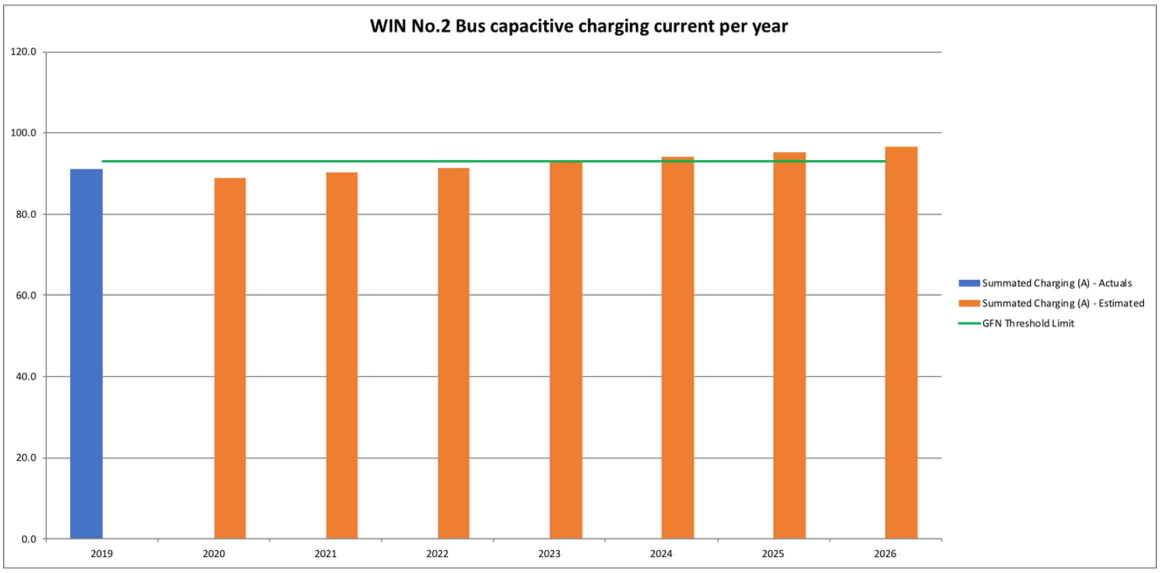
The figures below show the network capacitance forecasts for WIN.

Figure 6.17 WIN bus 1 capacitance forecast



Source: Powercor

Figure 6.18 WIN bus 2 capacitance forecast



Source: Powercor