Transmission System Plan - 2023 (DRAFT)

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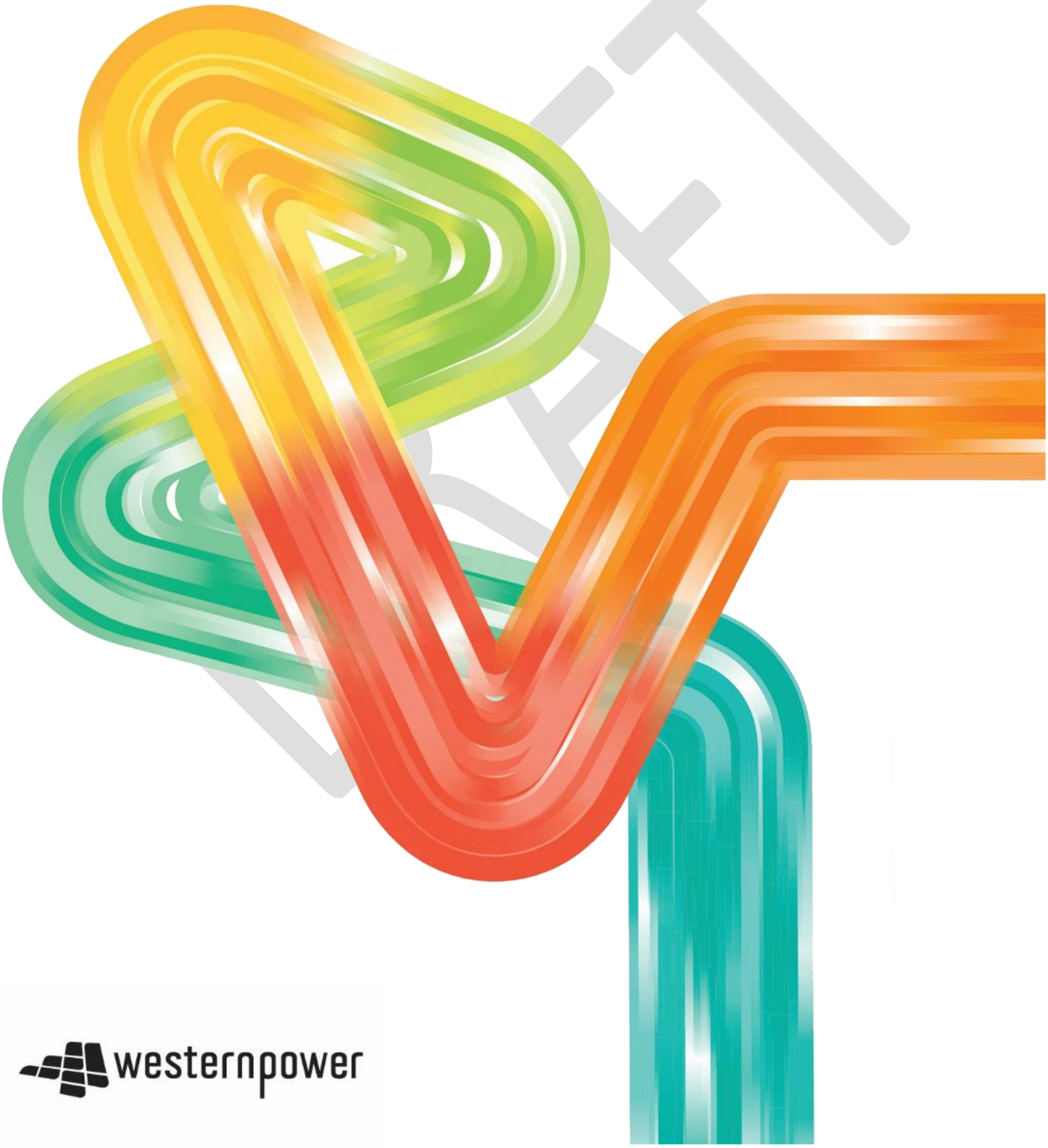

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Contents

Abbreviations

The following table provides a list of abbreviations and acronyms used throughout this document. Defined terms are identified in this document by capitals.

Term	Definition	Term	Definition
AA	Access Arrangement (AA5)	NCESS	Non Co-optimised Essential System Services
AEMO	Australian Energy Market Operator	NCR	Normal Cyclic Rating
APC	Annual Planning Cycle	NOM	Network Opportunity Map
BESS	Battery Energy Storage System	NQRS	Network Quality and Reliability of Supply Code
BTM	Behind-the-meter	NSP	Network Service Provider
CAG	Competing Applications Group	PASA	Projected Assessment of System Adequacy
CBD	Central Business District	PoE	Probability of Exceedance
DER	Distributed Energy Resources	PTA	Public Transport Authority
DPV	Distributed Photovoltaic	Pu	Per Unit
ELPS	Eastern Goldfields Load Permissive Scheme	PV	Photovoltaic
ELT2	Electricity Transmission Licence	RCP	Reserve Capacity Price
EMR	Electricity Market Reform	RFP	Request for Proposal
EMT	Electro-magnetic Transient	RIS	Required In Service
EOI	Expression of Interest	ROI	Registration of Interest
EPWA	Energy Policy WA	RTS	Real-Time Simulator
ERA	Economic Regulation Authority	SMI	System Minutes Interrupted
ESOO	Electricity Statement of Opportunities	SSB	Service Standard Benchmarks
EV	Electric Vehicle	SVC	Static VAR Compensator
GIA	Generator Interim Access	SWIS	South West Interconnected System
kV	Kilovolt	TR	Technical Rules
kW	Kilowatt	TSP	Transmission System Plan
MDT	Minimum Demand Threshold	VAR	Volt Ampere Reactive
MRWA	Main Roads WA	WAMPAC	Wide Area Monitoring Protection and Control
MVA	Mega Volt Ampere	WEM	Wholesale Electricity Market
MVAr	Mega Var	WF	Wind Farm
MW	Megawatt	WOSP	Whole of System Plan
MWh	Megawatt hours		

1. Executive Summary

The Transmission System Plan (TSP) is updated and published annually to provide a 10-year forward plan for investment in the transmission network[1]. This is the second TSP published and covers the FY2022/23 to FY2032/33 planning horizon to support alignment with Western Power's latest demand forecast and maintain continuity with existing network planning activities[2].

It is predominantly aimed at existing and prospective transmission customers who may be seeking to connect large-scale load, generation, and storage solutions to the transmission system. The TSP sets out potential investment opportunities, including alternatives to network augmentation, to alleviate identified network constraints and to maintain power system security and reliability in the South West Interconnected System (SWIS).

The TSP 2023 is published against a backdrop of an energy sector undergoing transformational change driven by a combination of economic factors, new technologies, changing consumer behaviours and new government policies. Demand for cleaner and alternative energy sources is changing the traditional electricity value chain. Increasingly, the network is acting as a platform for customers to choose how they want their electricity supplied and delivered. Increased penetration of renewable generation, and the displacement of traditional synchronous generation, has led to major changes to both ends of the electricity supply chain.

The State Government commitment to retire coal-fired generation, along with climate change commitments of net zero by 2050 (globally) and national emission reduction targets of 43 per cent by 2030 are driving action by industry in Western Australia and across the globe[3]. Achieving this target will require a substantial step change in demand, renewable generation, and energy storage.

Western Power is participating in the decarbonisation of communities and working with Energy Policy WA and other stakeholders to develop a grid vision to ensure an orderly transition from fossil fuels. This includes supporting broader decarbonisation by enhancing our technical solutions, products, and infrastructure to ensure grid security and reliability while facilitating further uptake and equitable access to renewable energy resources.

In this version of the TSP, the modelling assumptions have been updated to include coal fired generation retirements, battery energy storage solutions (BESS) and new renewable energy systems. Future TSPs are expected to provide greater insights into the performance of the transmission system and emerging constraints, solutions, and opportunities.

The commencement of security-constrained economic dispatch process driven by reforms to the WEM Rules, coincides with the publication of the TSP 2023, and will provide real-time and ex-post information about the impact of network constraints. Future TSPs will be able to use this and other market information to analyse trade-offs between efficient network investment and market costs, enabling Western Power to present network investment options that maximise benefits to the system and prospective transmission customers.

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1 Western Power is obligated under the Wholesale Electricity Market (WEM) Rules to publish a final version of the TSP before 1 October each year

2 Current demand forecasts were produced in 2023, looking forward from the period 2023/24 to 2033/34

3 https://www.industry.gov.au/news/australia-submits-new-emissions-target-to-unfccc

1.1 Key Findings of TSP 2023

- **Continuing demand uncertainty**. A combination of consumer behaviour, policy, weather, and technology changes means demand uncertainty is increasing markedly. Some of the key drivers of the demand uncertainty are:
  - Climate change impacts
  - Decarbonisation of industry
  - Developments in the energy industry such as hydrogen production
  - Distributed Photovoltaic (DPV)
  - Uptake of Behind-The-Meter (BTM) batteries
  - Increased Electric Vehicle (EV) usage
  - High variability in annual demand forecasts, present increasing challenges in planning for the transmission network and optimising timing triggers for new investment.
- **Transformation of energy generation.** A combination of market reform, expanding levels of intermittent generation technology and retirements of coal fired power stations is increasing uncertainty in the generation assumptions used to plan the network. The connection of renewable energy projects in viable regions is expected to drive transmission expansion into new locations in the SWIS. State Government in consultation with industry has released the SWIS Demand Assessment outlining the vision for energy transformation out to 2042. Refer to section 3.5.2.
- **System peak demand.** This is forecast to increase at an average annual rate of ~1% over the next decade, based on Western Power's 2023 Probability of Exceedance (PoE) 10 demand forecasts (covering the period 2022/23 to 2032/33)[4]. Although the growth in system peak demand is relatively low, compared to recent historical levels, areas including the Goldfields (East Region), Picton South and Kemerton-Marriott Road (South Region) and the Mandurah-Peel and Byford area (Metro South Region) remain constrained during peak demand conditions. Western Power has several projects progressing to alleviate these constraints and provide flexibility to facilitate higher utilisation levels. On a substation basis, the increase in peak demand is expected to result in 19 substation capacity issues requiring addressing over the study period.
- **High growth in new DPV connections is driving lower SWIS system minimum demands.** With more than 1,900 MW of DPV capacity connected on the SWIS, managing power system security and reliability during periods of low operational demand is becoming increasingly challenging, particularly in relation to voltage management and system stability. Minimum demand periods continue to present high risks for planning and operating the transmission network over the short- to medium-term.
- **The 330 kV network capacity.** Opportunities exists to connect large-scale generation and new large loads to the 330kV network. This network generally has low utilisation, however, access to the 330kV network may require network augmentation works to facilitate new customer connections. Western Power acknowledges the importance of connection opportunities particularly as industry transitions away from fossil fuels and further synchronous generation is retired (e.g., Muja and Collie).

[4] Excluding the step change in demand as a result of block loads

2. About Western Power

2.1 Our network

Western Power builds, operates and maintains the SWIS transmission and distribution network. The network services an area of 255, 064km^2; it incorporates more than 1.9 GW of rooftop solar (installed at more than 34 per cent of homes and businesses within the SWIS) and supplies approximately 1.2 million connected customers.

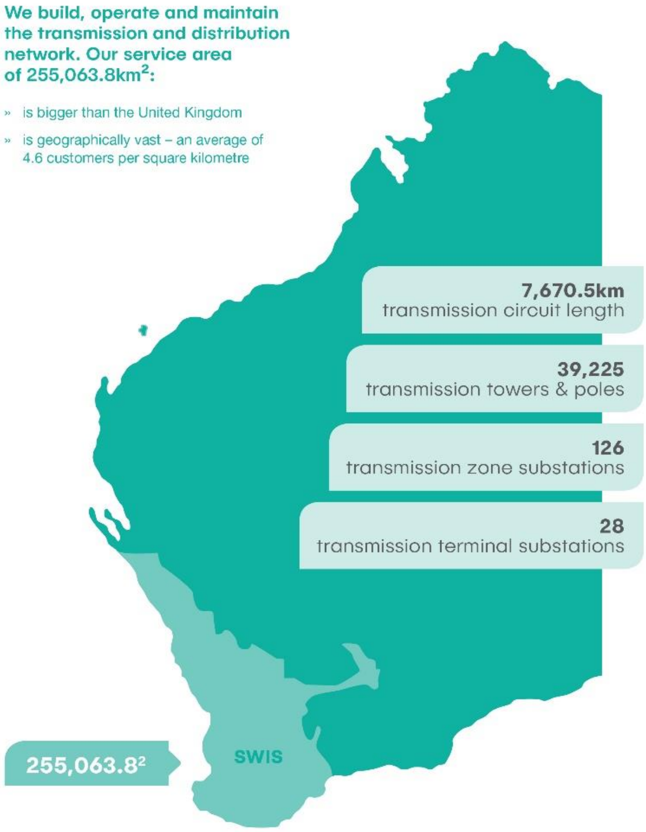

Figure 1: Overview of Western Power's Network[5]

The Western Power network is unusual for two reasons: its geographical size and overall low density of connections; and its isolation and lack of interconnections to any other large systems. These attributes make the network uniquely challenging for both operation and maintenance.

The network is inherently dynamic and complex, with changing customer needs and expectations. Western Power aims to be agile and responsive to these factors while maintaining a safe, reliable, and efficient electricity supply, to ultimately deliver an affordable and quality product for all Western Australians.

[5] As per 7 July 2023.

Figure 2 illustrates a simplified view of the bulk transmission network, including the grouping of six regions that share similar load characteristics and experience shared network issues.

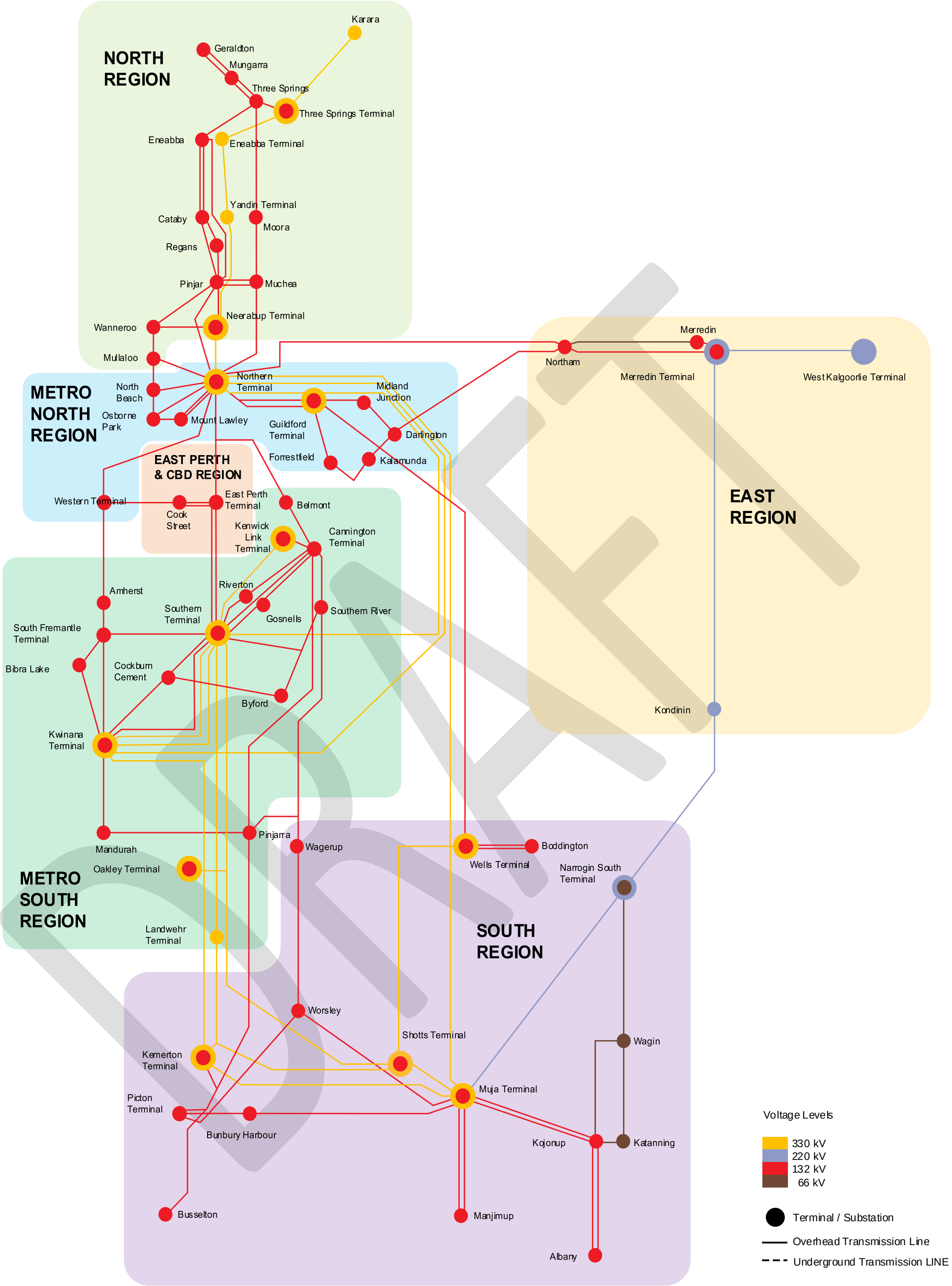

Figure 2: Simplified SWIS bulk transmission network diagram

3. Role of the Transmission System Plan

3.1 TSP requirements

Under section 4.5B of the WEM Rules, Western Power is required to develop a TSP that must:

(a) establish a plan for the efficient development of the transmission system for a planning horizon of at least 10 years

(b) meet the Power System Security and Power System Reliability requirements; and

(c) be in the long-term interests of consumers.[6]

The WEM rules require Western Power to include several considerations in the TSP:

(a) a summary of any significant costs to the WEM that have arisen, or may potentially arise, due to the condition of the transmission network, including:

i. binding network constraints, and the estimated market costs of those binding network constraints; and

ii. the frequency and magnitude of Constrained on Quantities and Constrained Off Quantities, including for facilities subject to network constraints.

(b) a set of investment options for developing the transmission system over the relevant planning horizon, which must consider network and non-network solutions to address the matters identified under clause 4.5B.4(a)

(c) analysis of market related data and an assessment of the costs and benefits, including to the WEM, of the identified investment options

(d) a recommended development path for the transmission system that would maximise net benefits and seek to minimise the long-term costs of electricity supplied to consumers; and

(e) a high-level assessment of how the recommended development path referred to in clause 4.5B.4(d) will meet the long-term interests of consumers.

This TSP addresses the above considerations by outlining:

- key strategies that influence and drive the development of the TSP
- planning methodology and assumptions used to prepare the TSP
- existing and emerging network constraints relating to power system security, reliability, technical requirements, and asset condition for the most efficient and likely generation scenario across the study period
- a set of network and non-network options to address the identified existing and emerging network constraints across the study period
- the current and future year expected maximum and minimum fault levels.

To the extent practicable, future TSPs will set out more comprehensive analysis and information on:

- Binding network constraints and their estimated market costs – upon commencement of security-constrained economic dispatch in the new WEM, Australian Energy Market Operator (AEMO) will

6 Clause 4.5B.3 of the WEM Rules

publish a constraints library including binding network constraints. AEMO will also publish a congestion information resource, the objective of which is to provide information on patterns and market impacts of network congestion[7]. Western Power will directly employ this information in its planning activities, including in the development of the TSP. The costs of network congestion will be assessed against the cost of network augmentation to help determine the optimal point at which network augmentation will become more economically efficient than the costs of constraining generators to relieve network constraints in the market

- A range of facility dispatch scenarios or credible dispatch patterns – this TSP based simulation studies and resulting network performance levels on an 'efficient and likely'[8] dispatch at peak and minimum demand operating conditions. Future versions of the TSP will build capability to cover a range of likely dispatch patterns
- Assessment of the development path for the TSP to maximise the long-term interests of consumers.

As part of the development of the TSP, Western Power is required to consult with AEMO and Energy Policy WA (EPWA) on:

- forecasted demand growth or reduction scenarios, including from the long-term Projected Assessment of System Adequacy (PASA)[9] and Whole of System Plan (WOSP)[10]
- scheduled connection of new loads or generators
- expected network modifications, augmentations or retirement of existing facilities or network assets that impact costs in the WEM
- credible contingency events and other commonly occurring credible contingencies that may significantly impact the SWIS
- a range of facility dispatch scenarios or credible dispatch patterns
- data, modelling, and results from the testing of scenarios in the WOSP, to the extent they are relevant as inputs to the TSP
- relevant information from the short-term PASA, medium-term PASA and long-term PASA studies conducted by AEMO under the WEM Rules
- other market information that the Network Operator, AEMO or the Coordinator considers relevant to meeting the requirements for developing the TSP, covered in this section 4.5B of the WEM.

Western Power recognises the importance of working with AEMO and EPWA in developing the TSP to align planning inputs such as demand forecasts, generation dispatch scenarios/patterns, credible contingency events, and market costs and impacts.

3.2 Interaction between the TSP and WOSP

The inaugural version of the WOSP was developed and delivered by the Energy Transformation Taskforce in August 2020[11]. The WOSP sets out a 20-year forward outlook for the sector, informed by engagement with industry stakeholders. Along with AEMO, Western Power was a key contributor to the plan.

7 Sections 2.27A and 2.27B of the WEM Rules.

8 An 'efficient and likely dispatch' scenario is a security constrained and economic dispatch based on merit order under system normal conditions that would produce the lowest cost to the system.

9 The Long-Term Projected Assessment of System Adequacy is an annual study required by the WEM Rules to be undertaken by the AEMO to determine, amongst other things, the amount of generation capacity needed in the SWIS to meet the forecast peak demand plus a margin.

10 The WOSP is required by the WEM Rules to be published by the Coordinator of Energy at least once every five years setting out a plan for the efficient development of the SWIS to meet power system needs, assisting in the transition to a lower-emissions system, identifying requirements for network investment and informing industry and policy makers regarding opportunities and future needs of the SWIS.

11 Available on EPWA's website: https://www.wa.gov.au/system/files/2020-11/Whole%20of%20System%20Plan_Report.pdf

The inaugural WOSP was a detailed study of how the SWIS may evolve in the next 20 years. Using data provided by industry, the plan modelled four energy scenarios to show how changes in demand, technology and the economy may shape electricity use and guide investments in large-scale generation, storage and network solutions to achieve lowest-cost electricity. The study aggregated the SWIS into 11 transmission zones (or nodes) to test the four energy scenarios, modelling the impact on emissions under each scenario.

Both the WOSP and TSP play a key role in planning for the transmission system over the short, medium and long-term. While the two plans share many key inputs and assumptions, they also have important differences, including but not limited to:

- Timescales – the TSP is focussed on presenting network performance and opportunities within a 10-year timeframe, whereas the WOSP provides a summary of four energy scenarios over a 20-year outlook. This is because the TSP outlines efficient investment opportunities for the transmission system and a 10-year outlook is realistic and reasonable for planning purposes
- Scenarios considered – the TSP presents network performance, opportunities and network development using a security constrained and economic dispatch based on merit order across a range of demand levels. The WOSP covers a broader range of energy scenarios to better understand the uncertainty of how changes in demand, technology and the economy may shape electricity use and guide investments to achieve lowest-cost electricity
- Identification of network constraints – major transmission inter-nodal constraints and augmentation are developed in the WOSP. The TSP will:
  - complement the WOSP analysis, while fine-tuning required augmentation technical details, costs, and binding constraint timelines
  - identify intra-nodal constraints and customer load/generation growth requiring network augmentation
  - optimise major network asset replacement works.

The WOSP includes provisions for identifying a proposed network augmentation as being of 'Priority Project' status when it demonstrates major benefits in addressing network constraints across multiple energy scenarios. Once a proposed network augmentation is given a Priority Project status and would potentially deliver benefits within a 10-year timescale, it is further developed and refined in the TSP. The inaugural 2020 WOSP did not identify any priority projects at the time, the next WOSP must be completed by the end of 2025.

Future TSPs will develop import and export boundaries that also align with the complete set of inter-nodal import and export boundaries presented in the WOSP. This will ensure better consistency in outputs when planning for the transmission system.

3.3 Interaction between the TSP and NOM

The Network Opportunity Map (NOM) is a regulatory requirement for Western Power outlined in chapter 6A of the Access Code, published together annually with the TSP on an annual basis on or before 1 October[12].

The primary purpose of the NOM is to present network opportunities on both the distribution and transmission system within a 5-year time horizon, with opportunities on the transmission system limited to network constraints at the zone substation level.

[12] https://www.wa.gov.au/sites/default/files/2019-08/ElecNetworksAccessCode.pdf

A network opportunity is the presentation of opportunities to providers of potential alternative options (all customers, industry, and market participants) to address transmission and distribution system constraints by providing alternative options to network augmentation.

This year's network opportunities focus on alleviating thermal and voltage capacity constraints. Future versions will include a broader scope of opportunities as Western Power increases its knowledge and understanding in this area. In addition, Western Power has decided to present a broader array of network opportunities on the transmission system beyond zone substation constraints, to promote transparency and to signal potential network opportunities as early as possible to assist in planning within the 10-year TSP timescale[13].

For further detail on network opportunities, how they are developed and the process to submit an alternative option, refer to the NOM 2022[14].

3.4 Interaction with latest Government policy announcements

3.4.1 Coal-fired generation retirements

In June 2022, the State Government announced the staged retirement of the Muja and Collie coal-fired power stations by 2030, as the continued uptake of rooftop solar and renewables has forced changes in the energy system to ensure a secure electricity supply and guard against higher power bills[15].

The retirement of Muja C G5 unit was completed in October 2022. The scheduled retirement of other coal-fired power stations includes Muja 'C' G6 in 2024, Collie Power station 2027 and the Muja D units G7 and G8 in 2029.

To ensure continued supply stability and affordability, the State Government has committed to an estimated $3.8 billion in new infrastructure investments in the SWIS, including wind generation and storage.

To determine the impact to the transmission network of these retirements Western Power has worked together with AEMO and other key stakeholders to ensure alignment on modelling assumptions, inputs and scenarios used to determine the impact of these changes to the transmission system. This has been included in this TSP.

3.4.2 SWIS Demand Assessment

The demand for renewable energy supply on the SWIS is expected to increase significantly following the Government commitment to achieve net zero emissions by 2050[16].

On 9 May 2023 the State Government released the SWIS Demand Assessment (SWISDA) outlining a vision of what the future transmission system might look like as a growing number of industries seek to decarbonise through electrification[17]. The SWISDA collated industry data to understand the potential change in electricity demand over the next 20 years, considering the requirements of existing industrial users on the SWIS and potential growth in new industries like hydrogen and critical minerals.

Western Power provided modelling and forecasting as a member of the SWISDA taskforce, helping to identify the extent of transmission network expansion required to transport the proposed industry load

[13] Where Western Power decides to procure a service in response to a network opportunity, the NCESS framework as outlined in sections 3.11A and 3.11B will apply.
[14] https://www.westernpower.com.au/suppliers/tenders-and-registrations-of-interest/network-opportunity-map/
[15] https://www.mediastatements.wa.gov.au/Pages/McGowan/2022/06/State-owned-coal-power-stations-to-be-retired-by-2030.aspx
[16] Climate Change Act 2022
[17] https://www.mediastatements.wa.gov.au/Pages/McGowan/2023/05/Green-energy-demand-to-transform-electricity-grid.aspx

around the SWIS. The fast-tracked assessment complements the 2020 Whole of System Plan by looking at the future growth of electricity demand that is largely driven by industry's action on climate change.

SWISDA has identified potential network augmentations options between 2023 and 2042 in a series of stages, setting the groundwork for the State Government to progress consultation and collaboration with existing and new industrial users to inform network investment, including mechanisms for industry contributions and third-party investments[18].

The first stage of works in the transmission expansion is now under way and the government has provided initial funding to commence the detailed scoping and planning activities and purchasing of long-lead items for initial upgrades.

At the time of publishing the draft TSP, the SWIS Demand assessment investments are proposed and the majority of the SWIS Demand assessment investments are at a very early stage of development and there is insufficient detail to include them in the analysis of this TSP. Western Power is committed to working and engaging with stakeholders and communities as we develop the future transmission network, including line route selection.

Two of the SWIS Demand Assessment investment do have an indicative high-level scope of works.

3.4.3 North Region Stage 1

The North Region stage 1 works proposes to upgrade one side of the existing transmission corridor starting in Northern Terminal Substation in Perth Metro to Three Springs Terminal in the Mid-West of the State. This upgrade from 132kV from 330kV will increase capacity to existing and future customers in the area, reduce network overloads by demeshing the 132kV network in the Neerabup Terminal area and increasing capacity. These projects are expected to be completed circa 2028.

Table 1: North Region Stage 1 - High Level Scope of Works

Item(s)	Work Package
1	Northern Terminal expanded: third 330/132kV Transformer
2	New 132kV transmission lines: Single circuit PBY-WGA and double circuit NBT-WGA and NBT-MUL
3	Reconfiguration of existing 132kV transmission lines: Create NBT-CKN, via CKN-WNO and a second NBT-PJR line
4	Neerabup Terminal expanded: Second 330/132kV Transformer
5	New 330kV transmission line: Double circuit NT-NBT
6	Conversion of existing 132kV line to 330kV operation: NT-PJR, PJR-RGN, RGN-CTB, CTB-ENB and ENB-TS removed and NT-RGT, RGT-YDT, YDT-ENT and ENT-TST 92 added
7	New Regans Terminal established: 2 x 330/132kV Transformers
8	Yandin Terminal reconfigured: Reconnect with new 330kV line instead of existing
9	Eneabba Terminal expanded: New 330/132kV Transformer and new double circuit 132kV line ENT-ENB
10	Three Springs Terminal expanded: Second 330/132kV Transformer and Reconfiguration of 132kV lines TST-TS

[18] https://www.wa.gov.au/government/document-collections/swis-demand-assessment

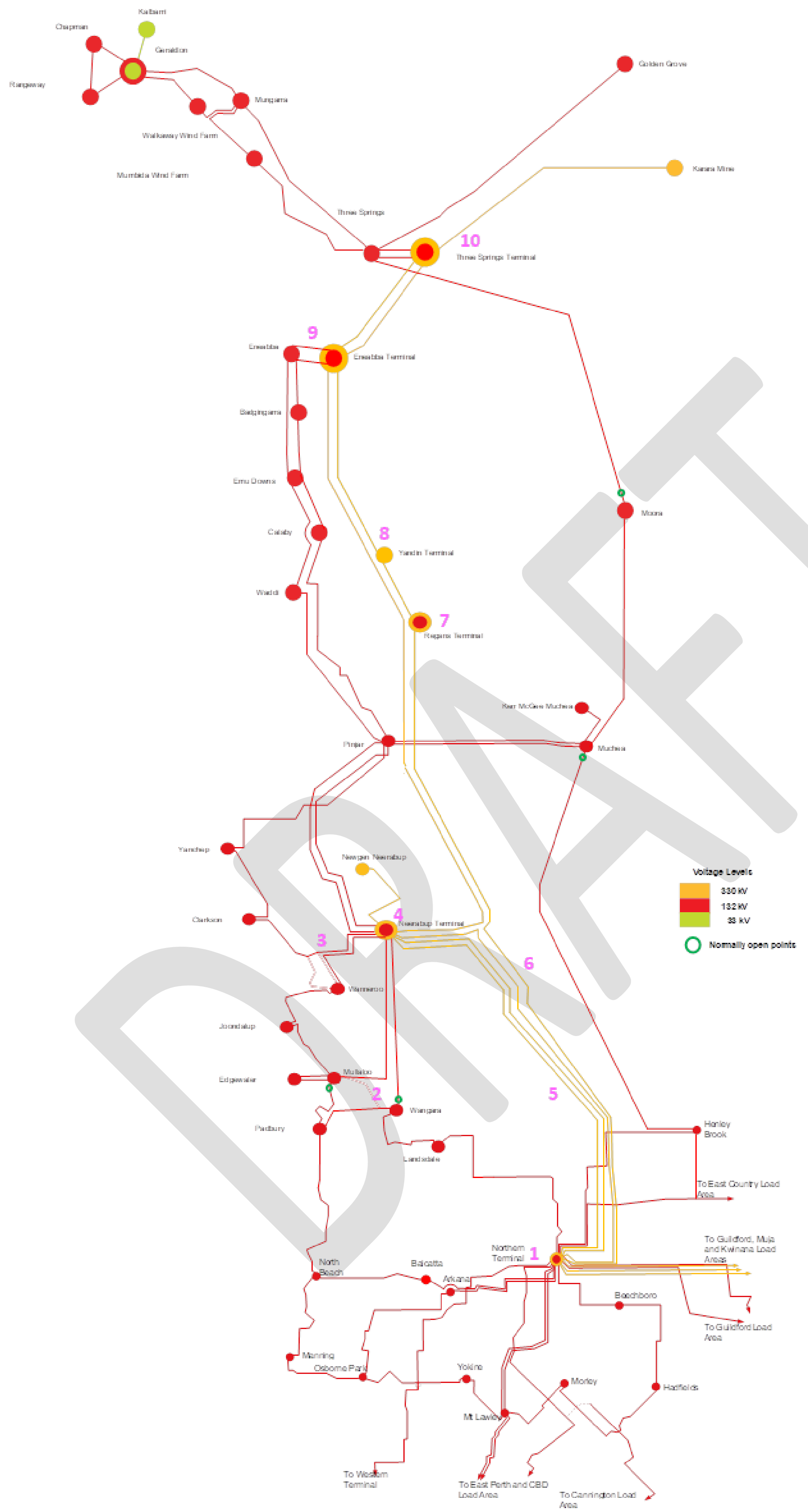

Figure 3: North Region Stage 1 - High level scope of work

3.4.4 East Region Stage 1

The East Region Stage 1 projects seek to increase the capacity of the existing Eastern Transmission Corridor from Muja to West Kalgoorlie. This will see the removal of limiting network components and the implementation of Dynamic line rating to reduce the network overloads under certain conditions. These projects are expected to be completed circa 2028.

Table 2: East Region stage 1 – High level scope of work

Item(s)	Work Package
1	Utilise Merredin Terminal - Northam 132kV conductor capacity via implementation of Dynamic Line Rating
2	Removal of other limiting factors at Northam 132kV (i.e., CTs, SCADA upgrade and protection limits).
3	Increase Muja-Narrogin -Kondinin circuit rating via removal of other limiting factors such as SCADA and secondary thermal rating limits.
4	
5	Improve Kondinin - Bounty conductor capacity via implementation of Dynamic Line Rating
6	Increase Collgar Terminal - Merredin Termina- Kondinin circuit rating via removal of other limiting factors such as SCADA and secondary thermal rating limits.
7	
8	Upgrade Muja Bus Tie Transformer 2 to a higher rated unit

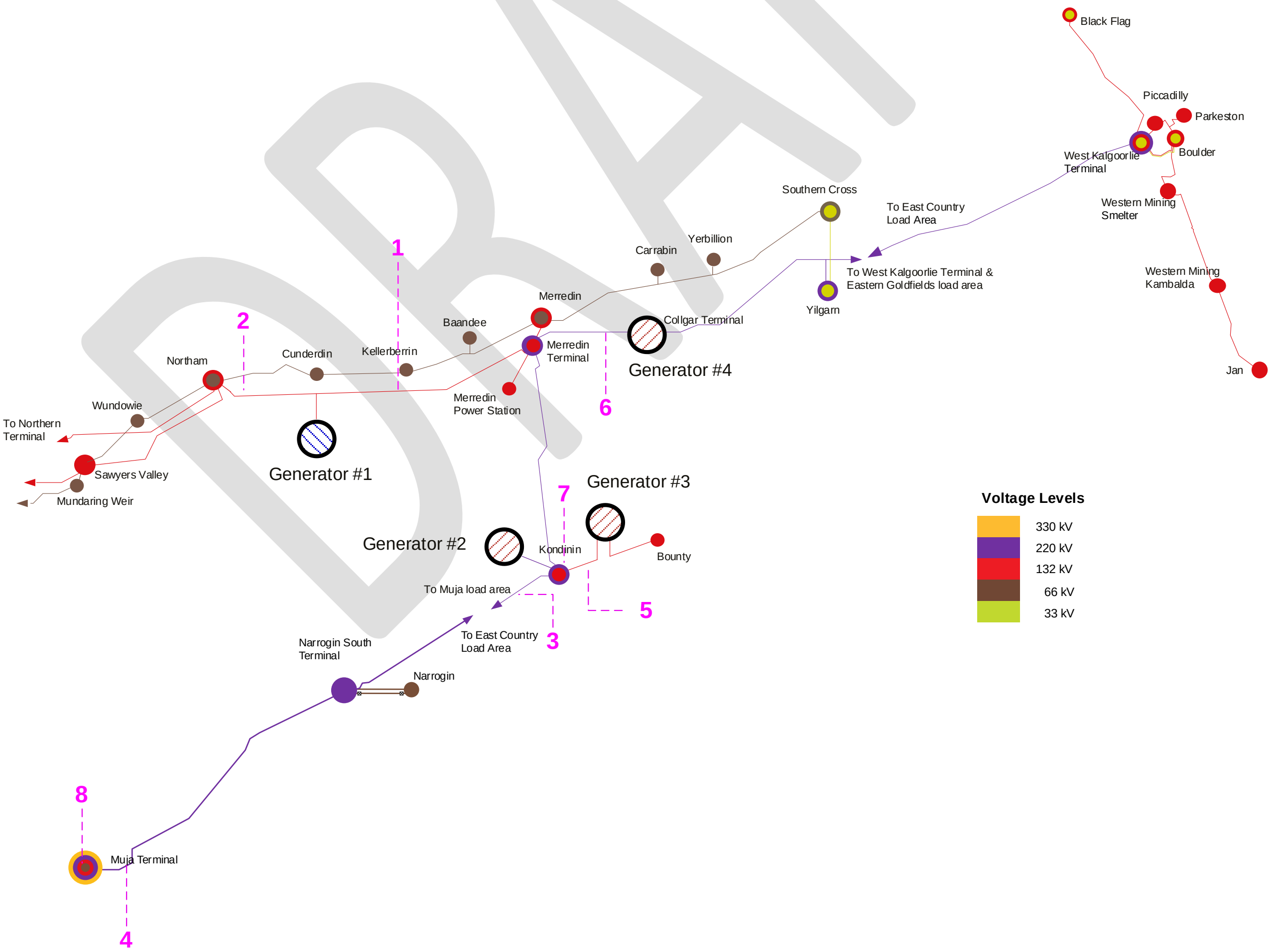

Figure 4: North Region Stage 1 - High level scope of work

4. Modelling Assumptions

4.1 Key input data and assumptions

Key input data and assumptions taken into consideration when developing the TSP include:

- WEM Technical Standards clause 2.8.14
- Power system security and reliability standards and requirements – section 3 under the WEM Rules and section 2 under the Technical Rules
- Any Priority Project identified in the WOSP or major augmentation that Western Power is able to progress in accordance with the Access Code. Note: No Priority Project has been identified under the 2020 WOSP
- Quality and reliability standards under part 2 of the Network Quality and Reliability of Supply Code 2005
- Any government policy that the Coordinator of Energy determines may impact on the development of the TSP, as may be advised by the coordinator pursuant to the consultation process referred to in clause 4.5B.6 or specified in the WOSP published by the coordinator under section 4.5A.
  - As discussed in section 3.4, the State Government has announced the retirement of the Muja and Collie coal-fired power stations by 2030, as well as the vision set out in the SWIS Demand Assessment.

4.2 Modelling parameters

- DigSILENT Powerfactory used to perform system simulation studies
- The study period is defined as the period 2022/23 to 2032/33
- Key network strategies, planning standards and guidelines were taken into consideration in developing the TSP, including but not limited to network Region Strategies, 66 kV Rationalisation Strategy, Transmission Planning Guidelines and Asset Management strategies
- Replacement of major transmission assets (i.e., power transformers and switchboards) are considered in creating long-term network development plans, as these assets are characterised as bulky, expensive and with long lead times, presenting opportunities to optimise replacement plans with other network investment drivers
- System simulations are performed using Western Power's maximum and minimum demand forecasts covering the period 2022/23 to 2032/33:
  - PoE10 system maximum and PoE50 system minimum demand forecasts for modelling peak and minimum demand conditions, respectively.
  - PoE10 and PoE50 substation non-coincidental maximum demand forecasts for modelling peak demand conditions
- Simulation studies to assess network security and reliability constraints are based on the 2022/23 demand forecasts. Refer to Appendix B: System Study Modelling Data for more detail
- Generation dispatch profiles for peak and minimum demand conditions are developed using a security constrained and economic dispatch based on merit order that includes operational advice provided by AEMO. Refer to Appendix B: System Study Modelling Data for more detail
- The generation fleet used to perform system simulations considers the current generation fleet and new generation connections that have become committed. It also includes the retirement of Muja 'C'

G5 unit (October 2022) and the scheduled retirements of Muja ‘C’ G6 (2024), Collie Power station (2027) and the Muja D units G7 & G8 (2029)

- The thermal transfer boundaries presented within each of the Region chapters (sections 10 to 15) are indicative in nature. The boundary capacities and their expected power flows are sensitive to the demand forecast and generation dispatch assumptions used. They should only be used to provide a guide for existing or new users prior to lodging a connection application, where more detailed connection studies will be performed to accurately assess the impact of a proposed connection
- The following definitions have been applied to the status of each project:
  - Completed – projects commissioned and in service within the period 1 July 2022 to 30 June 2023
  - Committed – projects with approved investment within the period 1 July 2022 to 30 June 2023
  - Proposed – proposals or projects that are expected to be developed and delivered within the study period, however, are yet to be committed.
- The Modelling includes all completed and committed projects - both customer projects and network augmentations
- Historically uncommitted customer connections are not presented in the TSP as they are still speculative in nature and their inclusion may misrepresent network performance levels and likely network development pathway. However, following the retiral of the coal generation at Muja and Collie a small number of yet to be committed customer projects have been included. These projects are very well progressed and, in some cases have commenced construction and they are expected to become committed in the near future. The projects have been included to ensure there is sufficient generation to meet demand specifically in the outer years of the study period
- A building block estimate tool is used to develop cost estimates where more detailed cost estimates are not available.

5. Planning Methodology

5.1 Overview

As a Network Service Provider (NSP) it is Western Power's role to provide transmission and distribution services to generators and load customers within the South West Interconnected Network. In providing these services Western Power operates the existing network and undertakes planning activities to ensure that new generator connections can be accommodated, with new and growing existing loads supplied according to established standards.

5.2 Annual Planning Cycle

The Annual Planning Cycle (APC) includes all the activities required to produce or update the 10-year Network Plan. The Network Plan includes all the network-related expenditure proposed over a 10-year period to meet a range of objectives and regulatory obligations, while maintaining an acceptable level of risk and performance for customers. It commences with the acquisition of latest telemetry and metering data, and culminates in a (constrained) list of risks and constraints that require addressing within the 10-year time horizon and publication of the TSP. The process takes approximately 12 months to complete with ad-hoc updates for any significant departures from anticipated results.

The Network Plan is usually finalised mid-way through the calendar year and provides a baseline for all network related expenditure across a 10-year outlook. It includes all committed projects, as well as candidates to address various risks and constraints in the network.

The delivery of the TSP is a key component of the APC.

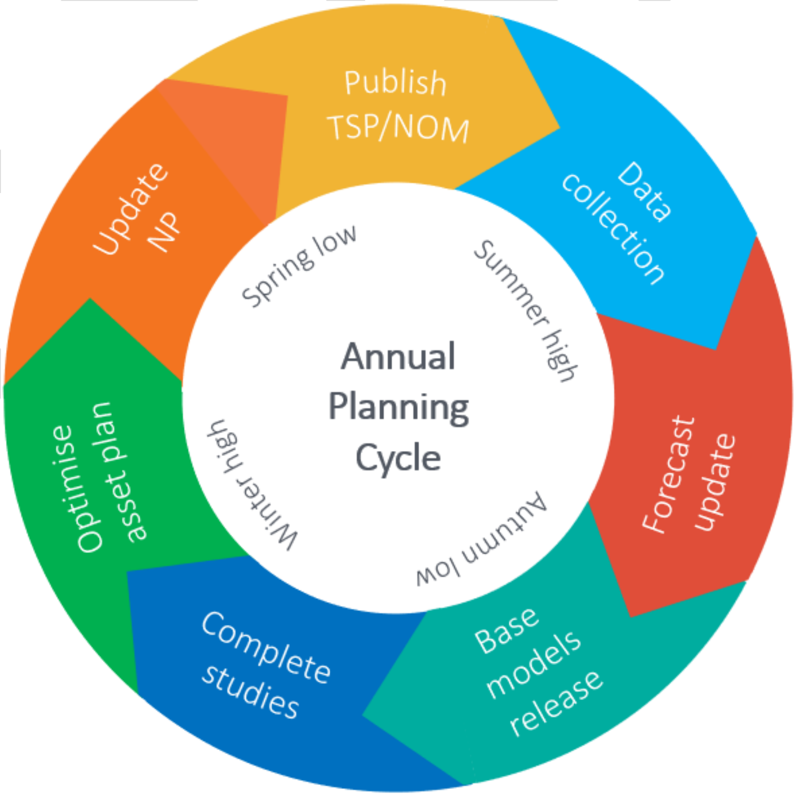

Figure 5: Annual planning review and reporting cycle

5.3 Network Planning Process

The Network Plan considers all relevant corporate objectives and network strategies and corporate objectives and follows a process to produce an optimised plan which meets known constraints.

This process includes an initial consideration of non-network solutions and application of new or emerging technologies.

5.3.1 Step 1 – Identify the Issues

Western Power routinely assesses the condition of the transmission network and its ability to supply existing and future demand against a range of requirements and obligations including the Technical Rules[19], WEM Rules[20], Network Quality and Reliability of Supply Code (NQRS)[21], Access Code and asset management requirements and objectives.

Key inputs to these assessments include:

- changes in forecast load and demand
- introduction of new loads or generation sources
- change in asset condition
- past reliability, safety, or other network performance characteristics.

This step generates a list of network or asset issues that need to be further examined and addressed.

5.3.2 Step 2 – Solutions

This step develops a series of options or solutions to address the emerging limitations in the network and asset classes. This includes analysis of trade-offs between operational and capital expenditure, asset replacement and maintenance solutions and initial assessment of alternative options to traditional network solutions.

In planning to meet peak demand levels, system studies are performed using a one-in-ten-year peak demand forecast and substation peak demand forecasts. This ensures worst-case bulk transmission limitations and worst-case localised overloads are identified. In planning for minimum demand levels, Western Power uses a one-in-two-year demand forecast. For both sets of demand conditions, the strategic direction needs to be considered along with long-term network plans, corporate performance measures such as reliability and safety, operational experience, and asset condition, to identify issues that are present on the network and deliver better and more efficient long-term outcomes.

Several generation scenarios are modelled into the probabilistic assessment of generation and load development options across a 10-year period, comprising the five-year access arrangement period and several years post the regulatory period to assess the performance of the transmission network. However, the TSP only presents network information based on a security constrained and economic dispatch based on merit order to identify constraints and establish network development plans.

Contingency analysis is then undertaken with the credible contingencies based on the TR and Planning Guidelines. All the credible contingencies are considered for any single contingency (N-1), a single contingency and outage (N-1-1) and a double contingency (N-2) analysis (Perth CBD).

19 Approved Technical Rules - Economic Regulation Authority Western Australia (erawa.com.au)

20 https://www.wa.gov.au/government/document-collections/wholesale-electricity-market-rules

21 https://www.wa.gov.au/organisation/energy-policy-wa/regulatory-framework

The outcome of this analysis is a set of high-level options that will be developed based largely on network solutions, but also include consideration towards various alternative options and non-network solutions. Western Power uses discounted cash flow techniques to assess the feasibility of all options and make recommendations.

To estimate cost, Western Power uses a blend of historical average unit rates, estimations and capital project building blocks based on previous projects and/or benchmarking. Specific project estimates are developed where there are unique project components, or a benchmark does not exist.

The output of this 'bottom up' approach is an unconstrained scenario which includes all the projects with respect to the network and asset needs.

5.3.3 Step 3 – Optimisation

The optimisation process includes actions such as:

- identification of network need and opportunities
- outputs from condition assessments
- verification of the lowest-cost option
- completion of risk reduction benefit assessments
- incorporation of the corporate strategy and plans for the network, including where higher capacity assets are needed in the long term, or taking into account utilisation and decommissioning of assets.

Where overlaps of drivers or dependencies with other projects exist on targeted assets, consideration is given as to how to optimise the solutions across projects.

5.3.4 Step 4 – Prioritisation

Assets within a particular group are prioritised and optimised in line with the relevant asset strategy, with the volume set by delivery constraints or the number of assets that can be addressed within the next 10 years. At an investment level these are prioritised by considering factors such as customers at risk, likelihood of failure, asset condition and criticality[22].

Some level of further optimisation is done at this stage with respect to the timing of works.

At the completion of this process, each portfolio is prioritised to satisfy any delivery or funding constraints.

Steps 1 to 4 provide a plan based on the least cost sustainable options and optimised across multiple network drivers and delivery.

5.3.5 Step 5 – Forecasting the Future Performance:

Following the end-to-end process, Western Power forecasts the performance of the network based on the proposed projects against measures such as Service Standard Benchmarks, anticipated safety performance, and movements in risk indices.

[22] Criticality, with respect to the network, is considered only for transformers, switchboards, and lines, which might take longer period to be replaced or brought back to service and supply a large number of customers.

6. Energy and Demand Forecasts

6.1 Demand Forecasting Methodology

Electricity demand and its patterns are one of the critical factors determining the size, timing and location of investments and other operational and strategic network decisions made by Western Power.

Western Power develops forecast models that can be classified as short-term load (one week), medium-term (up to 10 years) and long-term forecasting (up to 50 years). These forecasts may be segmented by customer type, tariff, and different network levels.

The models are also produced at different hierarchy levels, reconciled to ensure consistent results. Not all forecasts are developed for all scenarios, at all levels, or for every year.

Development of Western Power's forecast models is guided by three primary principles: accuracy, transparency, and evidence-based decision-making. The forecasting process checks the validity of forecasts by running statistical tests to ensure consistency at different levels of aggregation.

The accuracy of past forecasts is monitored, and any significant departures analysed for possible causes of inaccuracy. Adjustments are then made in the design of new forecast models, or the type and quality of data used. All input data is assessed for credibility and relevance before being approved for inclusion in the forecasting processes. Western Power measures and aggregates electricity demand averages based on five-minute intervals for the purposes of electricity demand forecasting.

Trends in connected customer count, imported energy from technology (mainly DPVs) and historical energy demand form the basis of most Western Power energy forecasts. Aside from reconciled and validated actual demand data, other inputs of note in the forecasting methodology are econometric forecasts obtained from reputable sources such as CSIRO and BIS Oxford which are analysed for impact and included where and if relevant.

Due to variability, forecasts are expressed at three probability of exceedance levels, rather than as single point forecasts. For any given season or year, PoE10, PoE50 and PoE90 are defined as:

- PoE10 where there is a 10% probability of demand exceeding the PoE10 value.
- PoE50 where there is a 50% probability of demand exceeding the PoE50 value.
- PoE90 where there is a 90% probability of demand exceeding the PoE90 value.

6.2 Customer Connections, DPV and Energy Forecasts

The method used to produce energy export forecasts from the network is based on three trends: customer connection numbers, adoption of DPVs, and energy imports from DPVs. This allows the model to reliably incorporate the effect of socio-economic and technological factors that result in highly dynamic and evolving energy consumption patterns.

- **Customer Connections Forecast –** includes economic forecasts, such as gross regional product, gross regional demand, and regional population to model estimated monthly connection numbers. The number of connections comprises counts of metered connections with a National Metering Identifier (NMI) and unmetered connections such as streetlights and bus stops.
- **DPV Capacity Forecast** - reliable long-term DPV installation forecasting is important for developing accurate forecasts for electricity consumption and demand. Although the mass adoption of DPV is a relatively recent phenomenon, the rate of adoption has had a material demand-reducing impact.

- **Energy Forecasts** - produces separate forecasts for exported energy from the grid and imported energy from DPV. The model produces monthly forecasts at hierarchy levels comprising tariff type, customer segment and substation levels. It also reconciles forecasts at different hierarchy levels.

6.3 Difference between energy scenarios and demand forecasts

Energy scenarios, unlike demand forecasts, look at historical data and certain assumptions of the future (to simulate scenarios such as climate change or high electric vehicle uptake. Demand forecasts make assumptions about what may happen in the future based on external forecasts on economic factors (BIS Oxford), population (WA Tomorrow) and forecasts using historical data relating to connection numbers, PV capacity, and imported and exported energy. The TSP uses demand forecasts rather than energy scenarios to present the most likely network development pathway.

Energy scenarios are similar to demand forecasts but are created with a specific future scenario in mind. Energy scenarios allow Western Power to better understand the range of sensitivities that may eventuate and allow the organisation to mitigate the risks of such scenarios by planning the future of the network accordingly.

6.4 Difference between WP and AEMO forecasts

AEMO produces annual demand forecasts as part of the Electricity Statement of Opportunities (ESOO) for the WEM for the purposes of assessing the adequacy of the power system to meet peak demand across a 10-year planning horizon. Although the inputs and methodologies that drive the development of Western Power and AEMO's 10-year demand forecasts are comparable they differ, resulting in different forecast outputs. Some of the key differences include:

- Western Power produces forecasts based on an 'as generated' basis, which includes gross generation for all market registered and unregistered generation facilities in the SWIS. AEMO demand forecasts do not include unregistered generation and auxiliary loads.
- Western Power demand forecasts are provided for a ten-year outlook compared to AEMO's five-year outlook.
- Western Power utilises five-minute intervals for aggregation of demand versus AEMO's 30-minute interval aggregation.
- Western Power utilises both calendar year and financial year in forecast reporting, while AEMO uses the capacity year, which begins in October.

Western Power consults with AEMO on assumptions and inputs maintain alignment and understand differences in demand forecasts.

6.5 Demand Forecasts

Western Power's forecasting reflects the challenges and opportunities the industry is facing, fuelled by the development of alternatives to electricity supplied by the network and in mass-market consumer technologies.

Demand forecasts are reviewed periodically to track changes in generation and demand and reveal network risks and development opportunities. The forecasts are based on both historical trends and key underlying factors such as weather, population growth, economic cycles, changing consumer behaviour and tariffs, and future technological advances.

Several forecasts are developed covering a 10-year period, comprising the five-year access arrangement period and several years post the regulatory period to assess the performance of the transmission and distribution networks. These include:

- Transmission network assessments – coincidental system PoE10 peak demand and system PoE50 system minimum demand forecasts used to model peak and minimum demand scenarios.
- Substation capacity assessments – non-coincidental system PoE10 peak demand forecasts.

6.6 Forecast Performance

6.6.1 Maximum Demand

Annual maximum demand on the network has been relatively variable since 2010, peaking above 3,800 MW in all years except one, though the differences between the 2022 and 2023 summer maximum forecast chart demonstrates the potential increased volatility in annual peaks (represented by the forecast band).

The 2023 summer maximum demand of 3,898 MW occurred on 3 March 2023. Maximum demand was 325 MW (4,223 – 3,898 MW) i.e. almost 8 per cent lower than in 2021, which was driven primarily by a mild summer.

DPV continues to push maximum demand later in the day, from between 17:30-18:30 and 18:00-19:00, closer to sunset when the impact of solar generation is minimal.

Figure 6 demonstrates that at a system level, the forecast from 2022 performed well, capturing the peak events from summer 2022 within the bounds of the PoE10 and PoE90 forecast. The outlook for the remainder of the forecast period is for the maximum demand trend to be broadly similar, as previously predicted, but with the PoE10 trendline slightly higher accounting for the greater volatility in annual peaks.

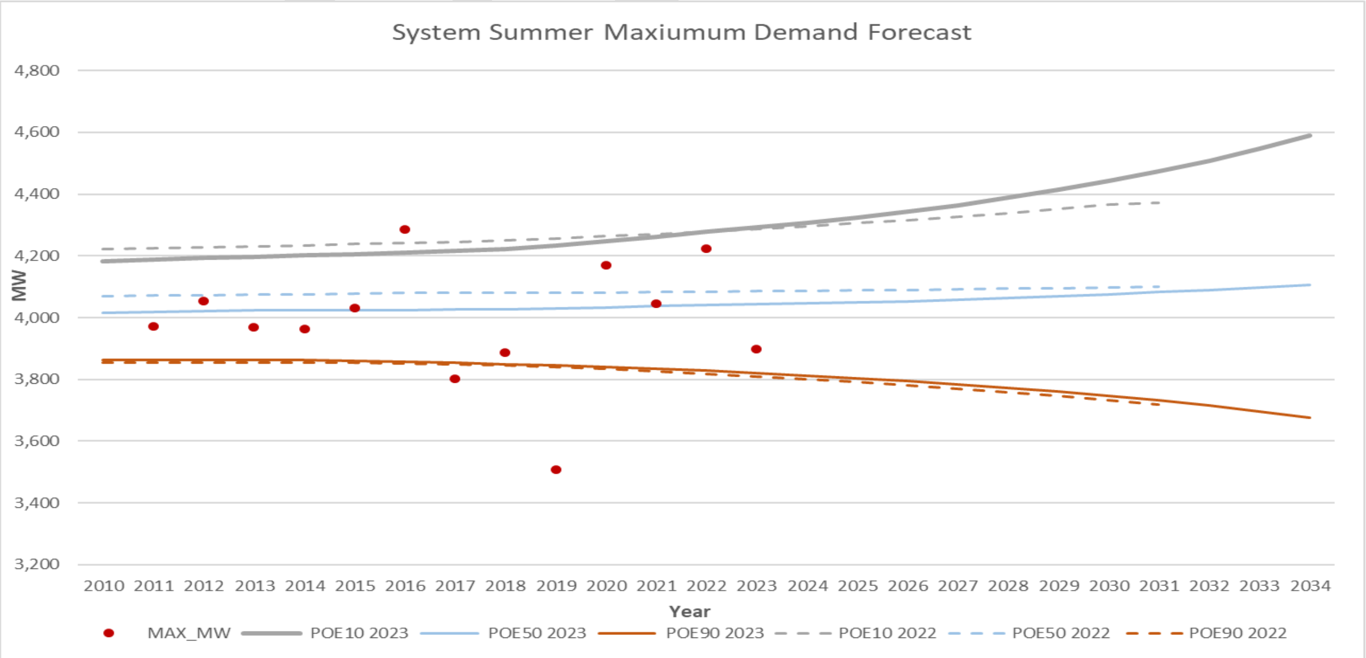

Figure 6: Historical and forecast system maximum demand – 2022 and 2023

6.6.2 Substation Performance

The system maximum demand forecasts were able to predict the peak events from the summer of 2022/2023 well, but conditions are more variable by locality. The following subset of substations provides a detailed look at performance by area. These substations have been selected as they are forecast to exceed their substation capacity within the next 10 years.

Byford

The actual maximum peak value in 2023 (summer) aligns with POE90 forecast from 2022, reaching 78.6 MW, 0.4% below forecast. The 2023 prediction shows a slightly smaller slope than the previous forecast, as the actual demand moderates from the extremely high demand recently experienced.

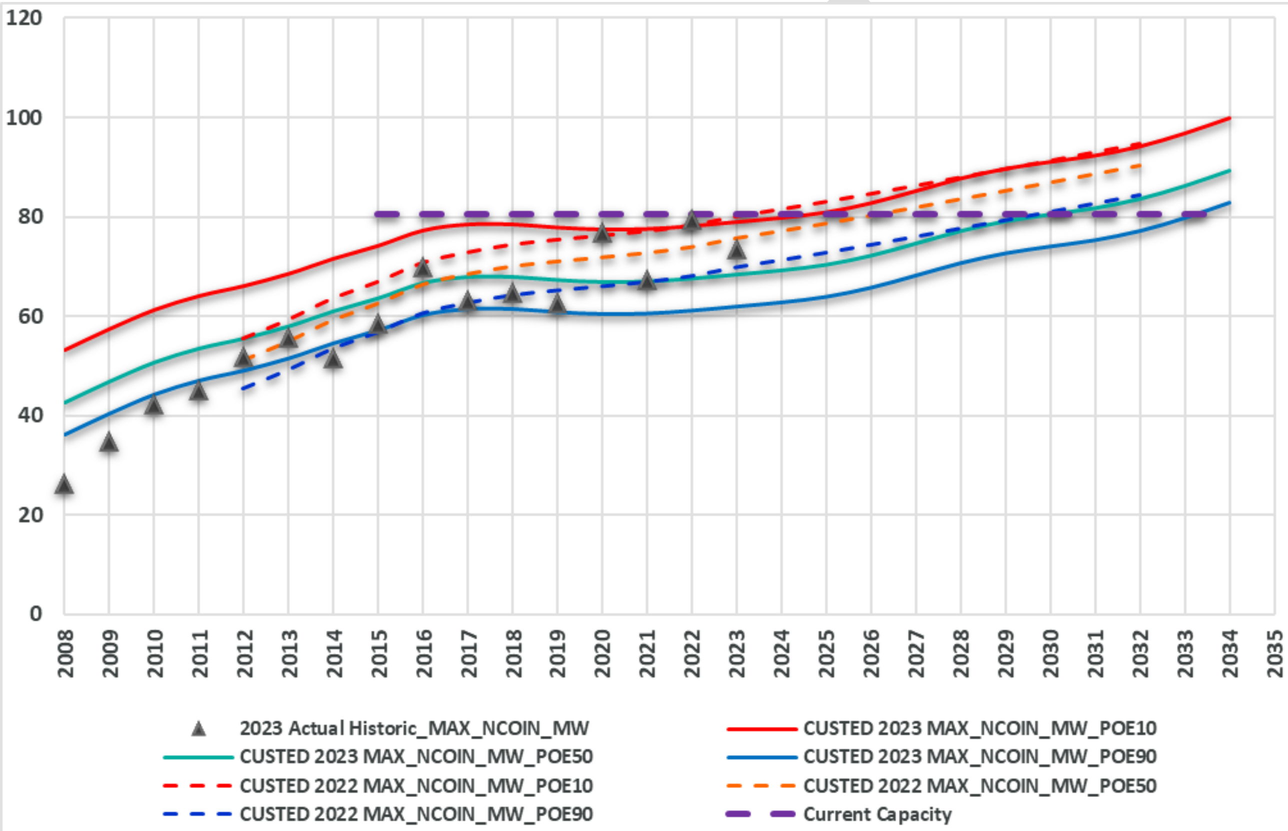

Figure 7: Byford non-coincidental historical and forecast maximum demand

Mandurah

This forecast performed well over time over both sets of forecasts. The actual maximum peak value in 2023 (summer) lay between the PoE50 and PoE10 forecast from 2022, reaching a peak value of 80.2 MW.

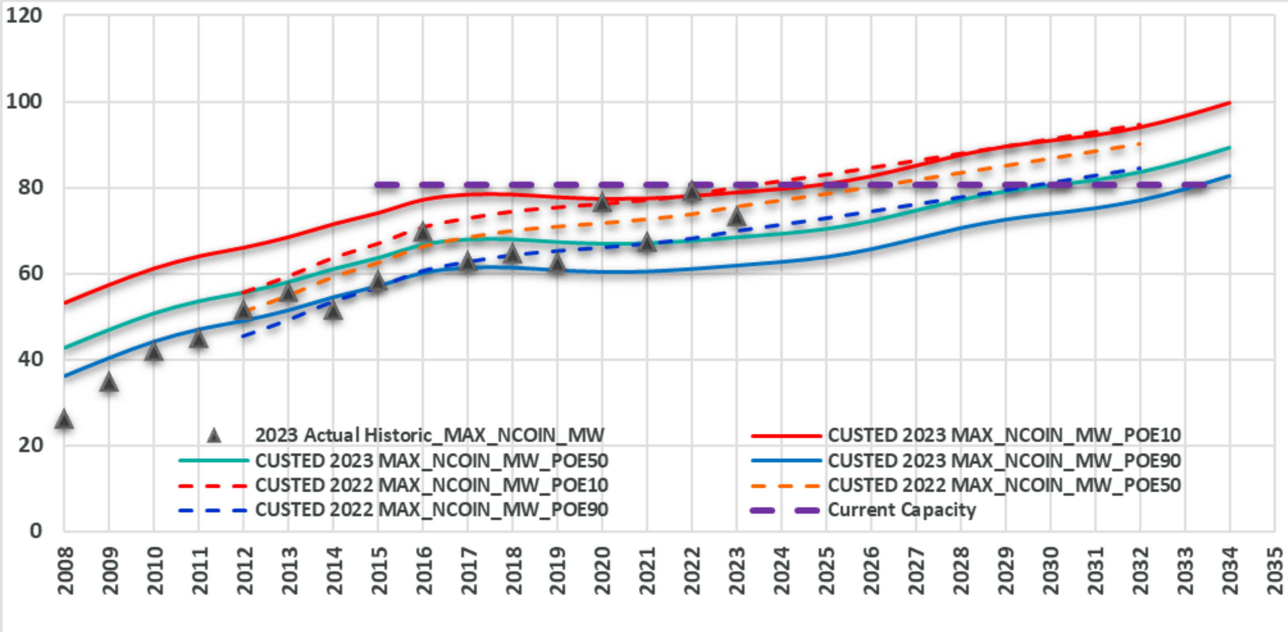

Figure 8: Mandurah non-coincidental historical and forecast maximum demand

Meadow Springs

The actual maximum peak value in 2023 (summer) is between POE50 and POE90 forecast from 2022, reaching 70.2 MW, 1% above POE90 forecast. The 2023 prediction shows a similar slope compared with the previous forecast, since the actual high values extended for 2 years of 2021 and 2022, then dropped in 2023. The drop in the actual demand in 2023 could moderate the future forecast, if the drop is not an anomaly.

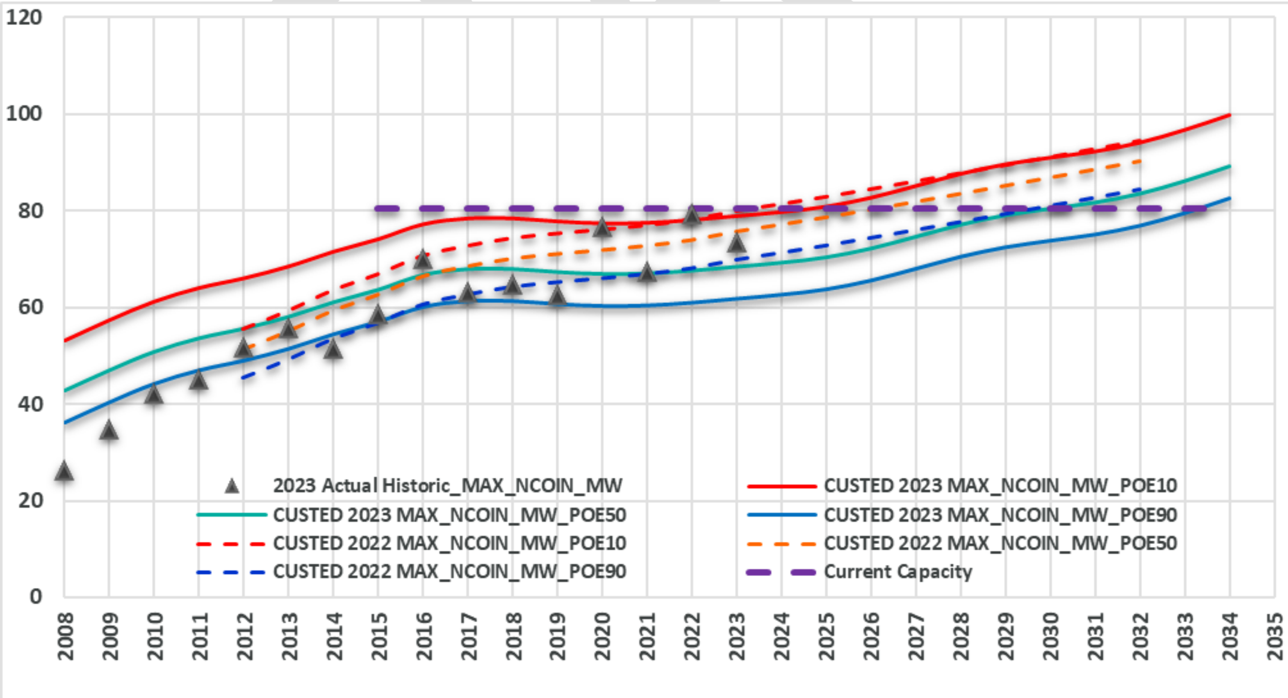

Figure 9: Meadow Springs non-coincidental historical and forecast maximum demand

Southern River

This forecast performed well over time over both sets of forecasts. The actual maximum peak value in 2023 (summer) lay between the PoE50 and PoE10 forecast from 2022, reaching a peak value of 84.1 MW.

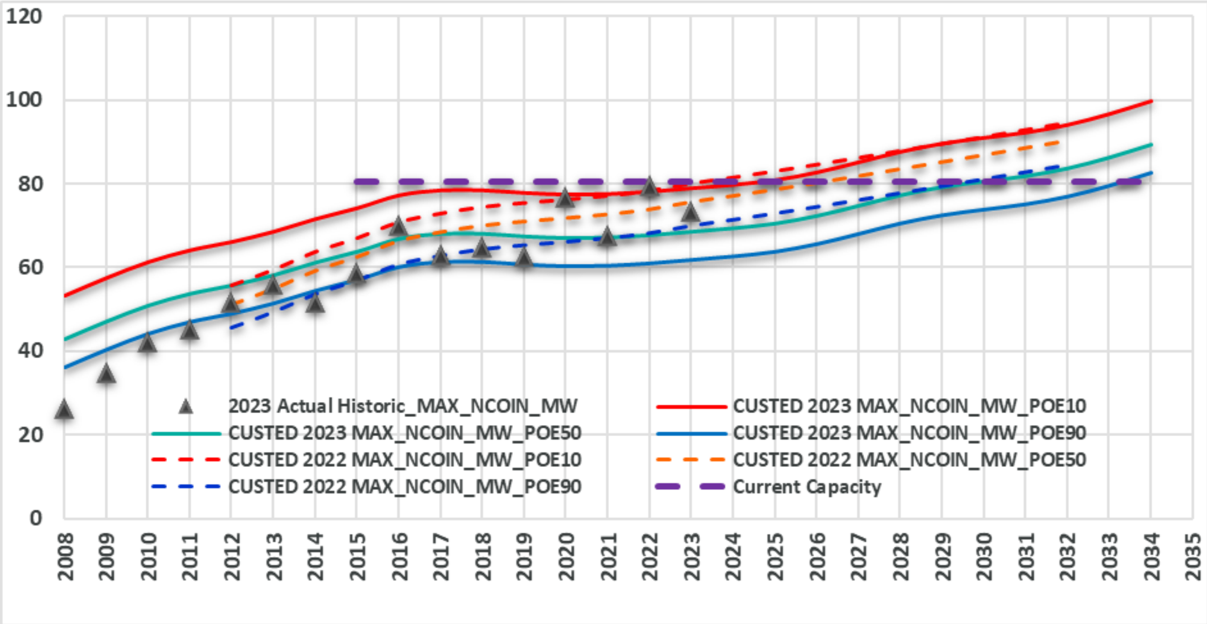

Figure 10: Southern River non-coincidental historical and forecast maximum demand

Waikiki

The actual maximum peak value in 2023 (summer) is between POE50 and POE90 forecast from 2022, reaching 73.3 MW, 1% below POE50 forecast. The 2023 prediction shows a similar slope compared with the previous forecast, due to the actual high value in 2022, and then drop in 2023. The drop in the actual demand in 2023 could moderate the future forecast, if the drop is not an anomaly.

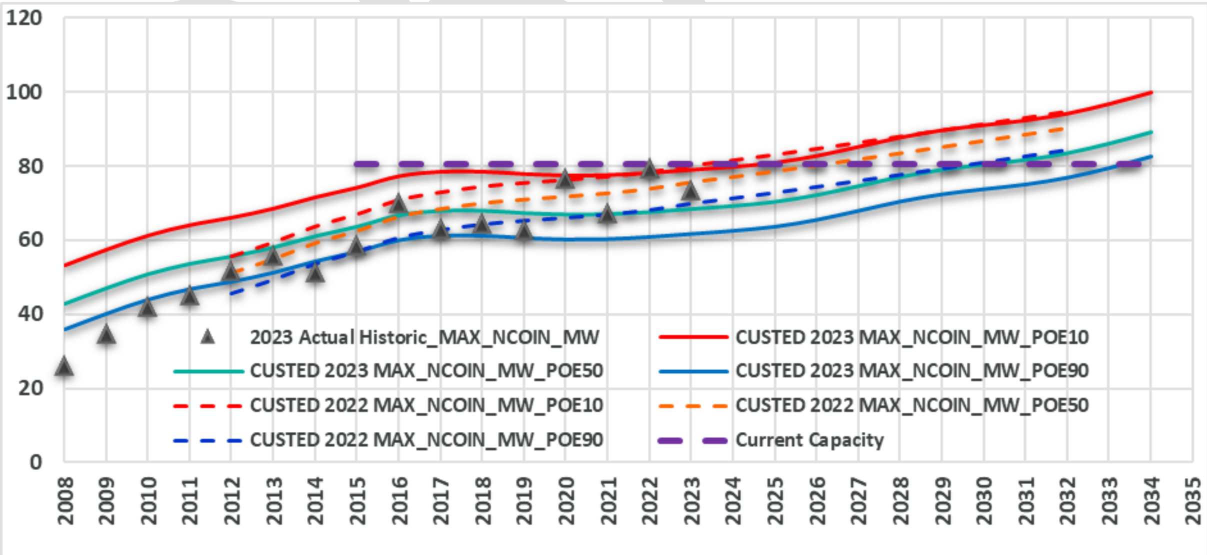

Figure 11: Waikiki non-coincidental historical and forecast maximum demand

6.6.3 Minimum Demand

Annual minimum demand on the network has consistently decreased and is forecast to continue decreasing. Increasing residential DPV is driving this decrease, with the lowest minimum loads typically seen during the middle of the day on weekends in spring and autumn. The 2022 and 2023 Daily Minimum Demand Forecast chart shows the decreasing minimum demand.

Minimum demand on the network is creating increasing challenges in planning and operation of the SWIS, including voltage management and system stability. Western Power and AEMO are working together to understand and quantify emerging risks to power system security during periods of low demand and to ensure appropriate responses, frameworks and mechanisms are in place and available to maintain power system security when called upon.

Minimum demand events tend to occur between 11:00 and 13:00 on non-working days in spring when temperatures are mild and skies are clear. Minimum demand records continue to be driven by the strong uptake of DPV. Previously, minimum demand would have expected to have occurred overnight and in the early hours of the morning. The current minimum demand record of 714 MW was set in 2022, occurring on October 16, 2022[23].

Minimum demand records are being broken each spring and the forecast trend is declining at a steeper rate than previously forecasted. It is notable that the observed system minimum demand has not yet fallen below PoE90. Refer to Section 16 for further details.

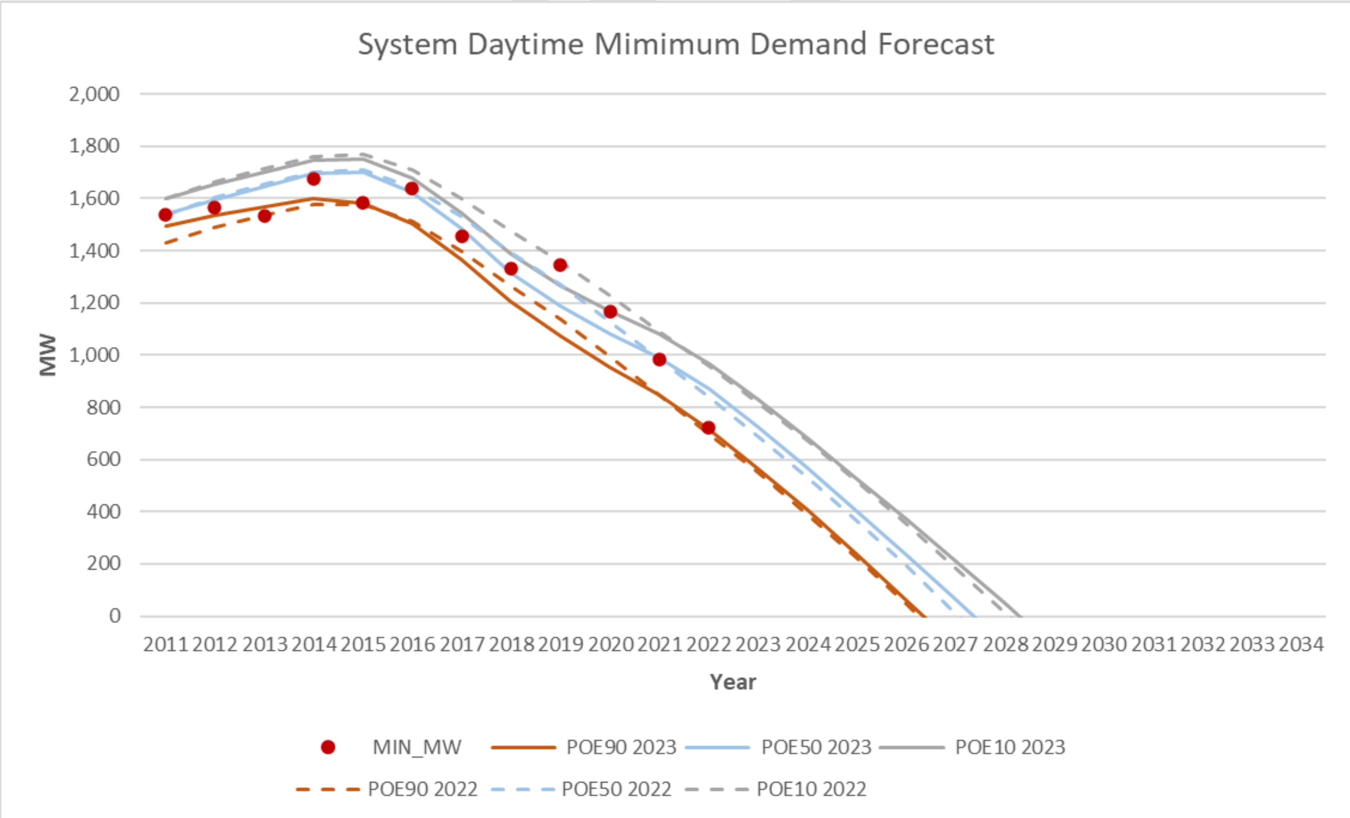

Figure 12: Historical and forecast system maximum demand - 2022 and 2023

[23] Equivalent to 626 MW, based on AEMO's demand definition – See 2022 ESSO - https://aemo.com.au/-/media/files/electricity/wem/planning_and_forecasting/esoo/2022/2022-wholesale-electricity-market-esoo.pdf?la=en

6.7 Technological Trends

The energy market is undergoing rapid change and the following technologies have been identified as having a significant impact on the evolution of the grid. The adoption and uptake of each of these technologies will have an impact on forecasting performance.

Battery storage

Western Power's PowerBanks are community batteries with the added benefit of virtual solar storage. They allow eligible households access to virtual storage in the battery to store their excess solar power. As of July 2023, there were 13 community batteries (1 x 105 kW capacity, 11 x 116 kW capacity and 1 BTM community battery). Additionally, there were 11,785 approved BTM battery applications with a cumulative storage capacity of 117MWh (95% of which is residential). Battery storage will also have an impact on energy demand forecasting, and scenarios are currently under development for future inclusion in energy demand forecasting.

Electric vehicles

There were an estimated 7,046 EVs registered in Western Australia end of December 2022, an increase from 4,321 in 2022, making up 0.43 per cent of registered vehicles in Western Australia. The WEM is expected to experience a massive uptake of electric vehicles in the coming decades and under the CSIRO's progressive growth scenario this number would increase to 1.75 million by in 2050, or to 2.6 million in the exploring alternative scenario and 3.6 million in the hydrogen export scenario[24].

Hydrogen

The Western Australian Renewable Hydrogen Strategy sets out ambitious goals to be achieved by 2030 including hydrogen exports, gas pipelines to contain up to 10 per cent renewable hydrogen blend, and renewable hydrogen use in mining haulage vehicles and transportation in regional WA. Western Power continues to receive strong interest in hydrogen facilities, which is anticipated to support decarbonisation and result in large new loads on the SWIS towards the end of the decade. This was a key input into the modelling developed as part of the SWIS Demand Assessment in section 3.5.2.

Electrification/Decarbonisation

Electrification is the shift from non-electric energy sources to electricity at its final point of consumption. It is an emerging trend that is being primarily driven by electric end-use technologies, public interest, and government policy aimed at reducing air pollution and mitigating climate change.

Electrification, depending on its extent and transition, could require a substantial and rapid response from the SWIS, which would be relied on to meet the additional growth in demand for electricity.

[24] Source: Graham, P.W. and Havas, L. 2022, Electric vehicle projections 2022, CSIRO, Australia

7. Generation Assumptions

Western Power's transmission planning responds to forecast growth in maximum demand and the expected connection of new generation[25]. Although Western Power's planning process considers a broader range of demand and generation scenarios, TSP 2023 only presents development plans for the most 'efficient and likely' peak and minimum scenarios. Western Power consults with AEMO to develop these scenarios as a security constrained and economic dispatch based on merit order that would produce the lowest cost to the system.

7.1 Constrained Network Access

From October 2023 the WEM commenced operation of a constrained market access. The new market arrangements will utilise a security constrained economic dispatch engine to ensure that a least cost outcome is achieved. However, when the new market commences, the cost of binding network constraints will be reflected in energy uplift payments made to generators to relieve network constraints. The cost of these uplift payments and other relevant information such as the location, magnitude and frequency of binding network constraints will now become available from October 2023 and will be used in future TSPs to determine the point at which network augmentation becomes more economically efficient when compared with dispatching expensive generators in the market.

Prior to October 2023, the WEM is operated under an unconstrained network access framework where generators must fund network augmentations to maintain the unconstrained access of incumbents. In recent years, interim arrangements including runback schemes and Generator Interim Access (GIA) have allowed generators to avoid funding augmentations by agreeing to reduced levels of access. Since June 2020, five generators have been connected under GIA arrangements.

[25] New generation entrants are considered in system studies for the TSP when they have become committed and been signed a 'Network Access Application Offer'

8. Technical Rules Compliance

Western Power is regulated in accordance with the Electricity Networks Access Code 2004 (the Code) by the Economic Regulation Authority of Western Australia (the ERA).

The Technical Rules is a document mandated under Chapter 12 of the Code, with the scope of the Technical Rules outlined in Appendix 6 of the Code. The Technical Rules outline the obligations of Western Power and connecting users regarding planning, design, operation and performance of the network and facilities and equipment connected to the network. In planning transmission network investment, Western Power aims to comply with the Technical Rules while maintaining an acceptable level of risk and performance for customers in line with the broader network development plan.

The Technical Rules commenced on 1 July 2007 with a provision that the existing network and all connected user facilities (at 1 July 2007) were deemed to comply with the Technical Rules. This deeming provision enables pre-existing parts of the network to not be required to be upgraded if they operate satisfactorily to the new standard. Any equipment amended or modified since the initial commencement of the Technical Rules must comply with the Technical Rules. However, it is recognised that over time changes in technology, customer needs and network configuration have made it difficult to comply with some of the requirements in the Technical Rules. Therefore, the Code includes provisions that allow Western Power to apply to the ERA to obtain an exemption from one or more requirements of the Technical Rules. The process for obtaining a derogation for Western Power is described in Clauses 12.40 to 12.49 of the Code. Network users can also seek an exemption from their own obligations by applying to Western Power as described in Clauses 12.33 to 12.39 of the Code.

Information related to Western Power and the Technical Rules is available on the ERA website[26]. Chapter 10 onwards, which provides detailed regional analysis, also discusses Technical Rules where relevant.

The July 2023 Technical Rules review submission to the ERA will better address emerging customer and network needs, reduce the need for exemptions and make the network planning process more flexible and efficient. ERA's review of the submission may include a public consultation component, and an outcome of the review is expected to be known by mid-2024.

26 www.erawa.com.au/electricity/electricity-access/western-power-network/technical-rules

9. Key Network (Region) Strategies

Western Power's network covers the area from Kalbarri in the north to Albany in the south, and from Kalgoorlie in the east to the metropolitan coast.

Western Power's network has been segmented into six geographic regions for the purposes of network planning. Dividing networks into regions is designed for ease of network planning as these regions can share similar load characteristics and experience shared network issues.

Figure 13 provides an illustration of the geographic boundaries between regions, with three regions covering the metro and three regions covering the remaining regional parts of the SWIS.

Figure 13: Western Power's transmission network regions

Each of the six regions in the SWIS are discussed in detailed throughout sections 10 to 15. These sections include:

- A description of key regional characteristics of the region including:
  - geographical boundary
  - the type of load and generation mix
  - existing network supply
  - key developments.
- An overview of network performance levels including the following performance parameters:
  - thermal capacity
  - voltage capacity
  - fault levels
  - stability
  - reliability
  - asset condition (major network assets only).
- A list of Western Power's optimised (completed, committed, and proposed) network development plans (considering both network and non-network options) to address the identified network constraints over the study period.
- A list of network opportunities to provide alternative options to alleviate or reduce network constraints and subsequent proposed network augmentation. For more information relating to what is a network opportunity and how and when to submit an alternative option, refer to the NOM 2022.

10. North Region

10.1 Geography

The North Region covers the northern most part of the Perth metropolitan area, from Landsdale and Wangara in the south to Yanchep in the north, extending into northern rural areas via Pinjar and Muchea, and to Geraldton at the northern extremity of the Western Power transmission network. The North Region extends inland about 150 km to service the northern wheatbelt.

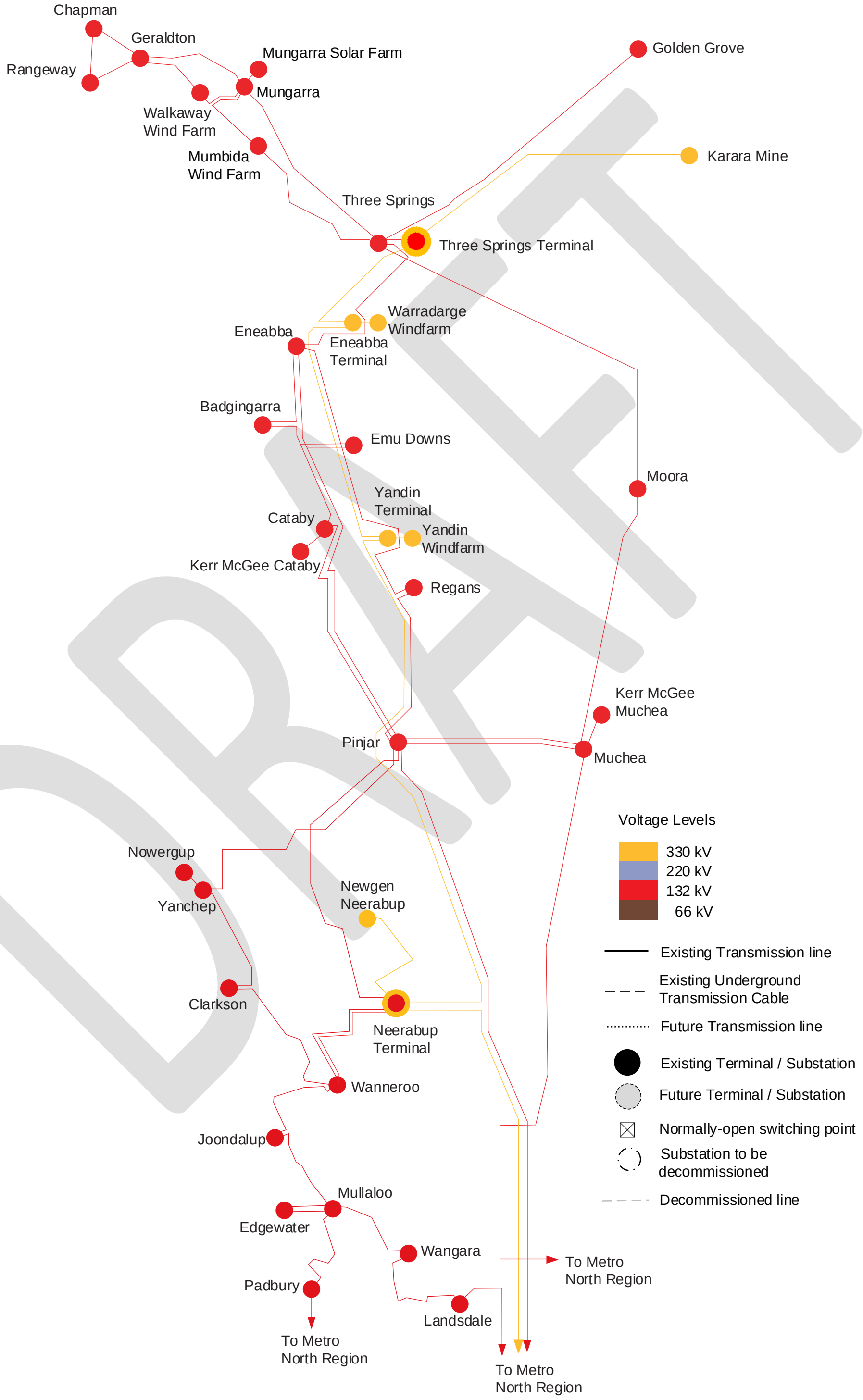

Figure 14: Western Power's North Region – Network Diagram

Western Power's North Region has four terminal stations and 21 zone substations that are owned and operated by Western Power. The other transmission sites in the North Region are customer owned substations.

Terminal substations

- Eneabba Terminal – 330/132 kV
- Three Springs Terminal – 330/132 kV
- Neerabup Terminal – 330/132 kV
- Yandin Terminal – 330/132 kV

Zone Substations / WP Substations

- Badgingarra – 132 kV
- Cataby – 132 kV
- Chapman – 132/11 kV
- Clarkson – 132/22 kV
- Eneabba – 132/33 kV
- Geraldton – 132/33 kV
- Joondalup – 132/22 kV
- Rangeway – 132/11 kV
- Regans – 132/33/22 kV
- Landsdale – 132/22 kV
- Moora – 132/33 kV
- Muchea – 132/22 kV
- Mungarra – 132k kV
- Mullaloo – 132/22 kV
- Mumbida – 132 kV
- Padbury – 132/22 kV
- Pinjar – 132kV (switchyard)
- Three Springs – 132/33 kV
- Wangara – 132/22 kV
- Wanneroo – 132/22 kV
- Yanchep – 132/22 kV

Customer Substations

- Edgewater – 132 kV
- Golden Grove – 330 kV
- Kerr McGee Cataby – 132 kV
- Kerr McGee Muchea – 132 kV
- Karara Mine – 330 kV
- Mungarra Power Station – 132kV
- Mungarra Solar – 132 kV
- Mumbida WF – 132 kV
- Nowergup – 132 kV
- Walkaway WF - 132kV
- Warradarge WF – 330 kV
- Yandin WF – 330 kV

10.2 Regional Characteristics

10.2.1 General

The network covering the northern most part of the Perth metropolitan area supplies predominantly residential loads and a mixture of commercial and light industrial loads.

The network covering the area further north of the Perth Metropolitan area primarily supplies rural, agricultural, and mining loads with urban areas concentrated in the City of Geraldton and Kalbarri in the most northern part of the network.

10.2.2 Generation

There is about 800MW of renewable generation in the region. In addition, there is also significant gas-fired generation at Neerabup terminal, Pinjar and Mungarra. Due to the availability of fuel resources in the North, particularly wind and other renewable sources, this region has the potential to become a significant exporter of energy. However, the current transfer capacity is significantly utilised and generation in this region is likely to be subject to network congestion until further network augmentation to improve the transfer capability is delivered. There are further transmission investments under development to increase network capacity and these are outlined in section 3.5.3.

10.2.3 Existing Transmission Network Supply

The North Region transmission network consists of a mix of 330 kV and 132 kV networks. The 330 kV networks provide bulk power transfer capability through the region and the 132 kV networks primarily provide supply to load centres. The 330 kV networks are linked to the 132 kV networks via the Neerabup and Three Springs terminal stations. The 330 kV networks and 132 kV networks in the region are planned and operated to a N-1 standard, other than some mining load customer connections that have N-0 supply arrangements.

10.2.4 Key Developments in the Region

Large-scale windfarms were recently connected at Warradarge and Yandin on the 330 kV network and at Badgingarra on the 132 kV network. Despite network constraints in the region, GIA has enabled the connection of the windfarms under an interim constrained network access regime, these constraints will be managed via the dispatch engine under WEM constrain access market arrangements.

There has been considerable interest in new network connections for new large-scale wind and solar facilities in the northern areas, where wind and solar energy sources and available land are relatively abundant.

10.3 Performance

This section presents the network performance for the North Region over the study period.

10.3.1 Thermal Capacity - Boundaries

The following assumptions were made in developing the import and export boundaries:

- Import boundaries consider peak demand and security constrained and economic dispatch conditions.
- Export boundaries consider peak demand and maximum generation dispatch conditions (within boundary).

Import Boundaries

Figure 15 highlights the network import boundaries in the North Region. These boundaries are defined using the worst contingency (↯) and the worst overload circuit (*) as shown in **Table 3**.

The expected transfer and transfer capacity for each of the import boundaries across the study period are shown in **Figure 16** to **Figure 19**.

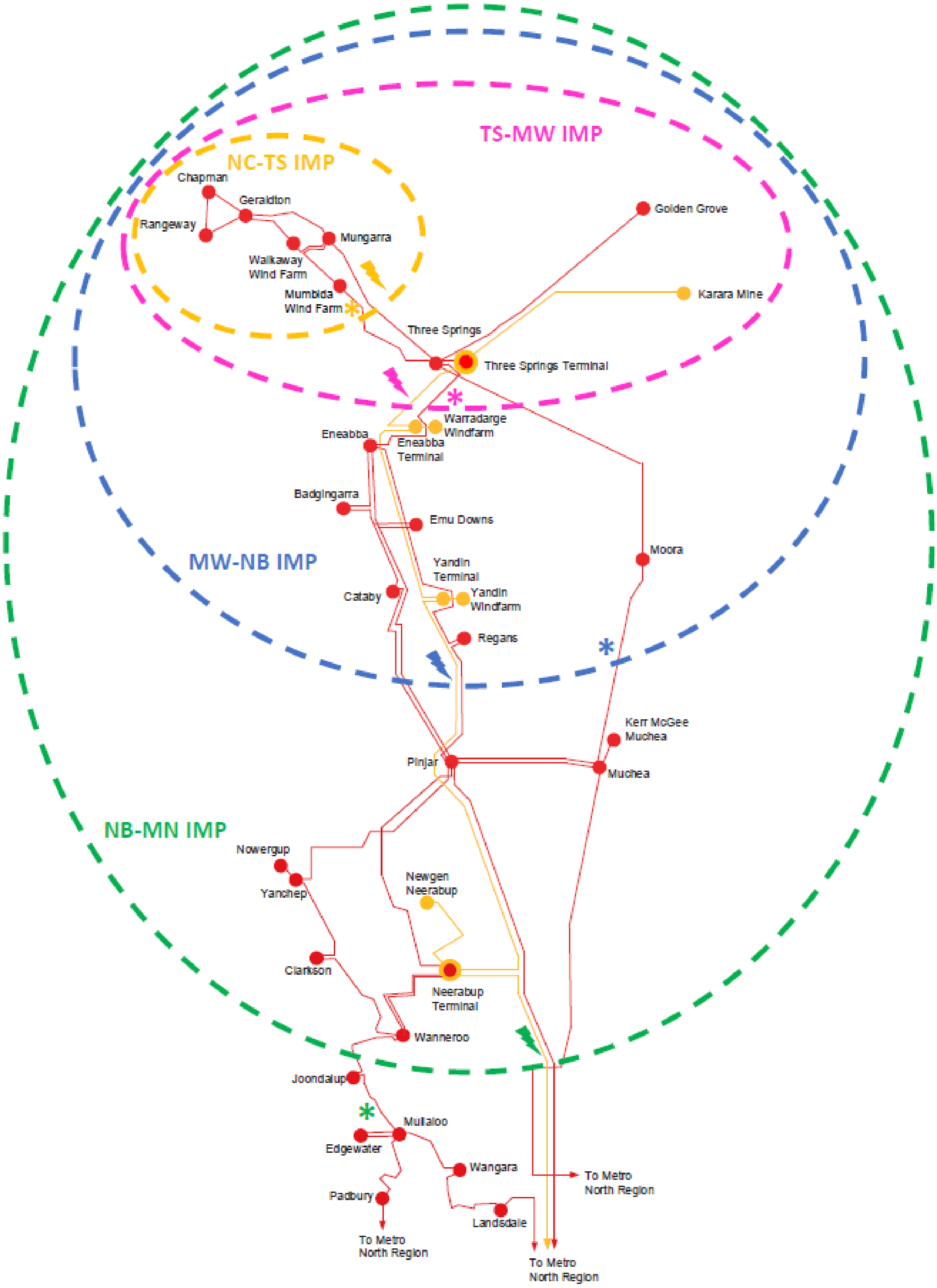

Figure 15: Network thermal import boundaries in the North Region

Table 3: Thermal import boundaries characteristics – North Region

Characteristics	Import Boundaries			
	NC-TS IMP	TS-MW IMP	MW-NB IMP	NB-MN IMP
Worst contingency	Three Springs to Mungarra 132 kV line	Eneabba Terminal to Three Springs Terminal 330 kV line	Neerabup Terminal to Yandin Terminal 330 kV line	Northern Terminal to Neerabup Terminal 330 kV line
Contingency type	N-1	N-1	N-1	N-1
Worst circuit	Three Springs to Mumbida 132 kV line	Three Springs to Eneabba 132 kV line	Muchea to Moora 132 kV line	Mullaloo to Joondalup 132 kV line

Other than for the NC-TS IMP boundary, it is important to note that the available thermal capacity in the remaining import boundaries may be lower than shown, as a new load connection looking to connect within a subset import boundary may bind first (i.e., at either the transmission network or substation level).

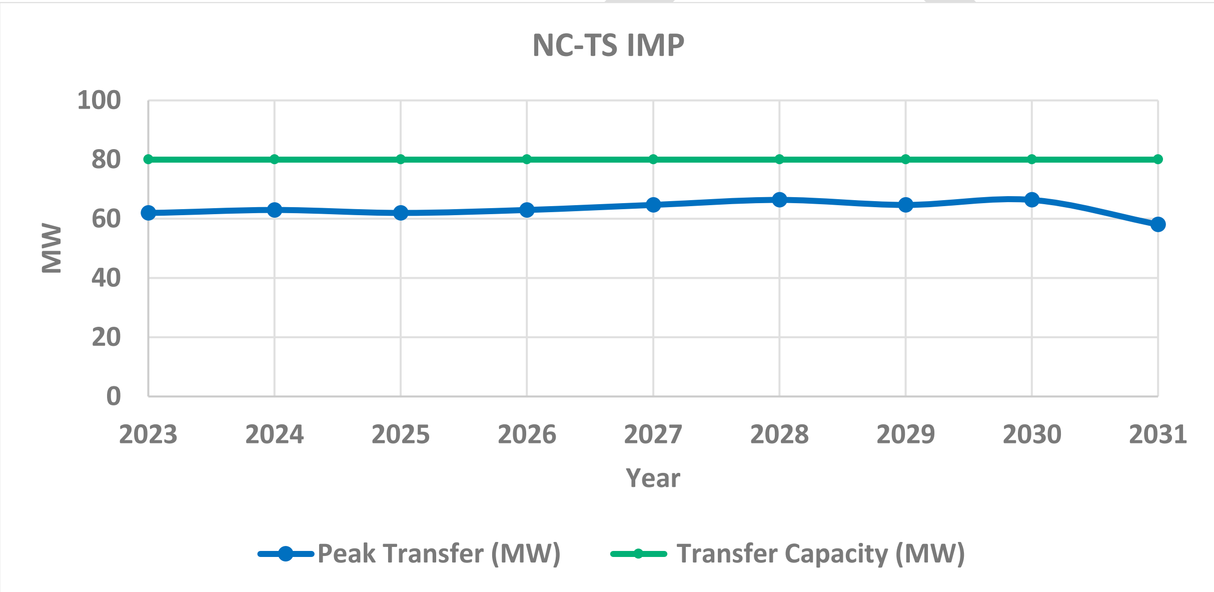

Figure 16: Expected transfer and transfer capacity in NC-TS IMP boundary – peak demand

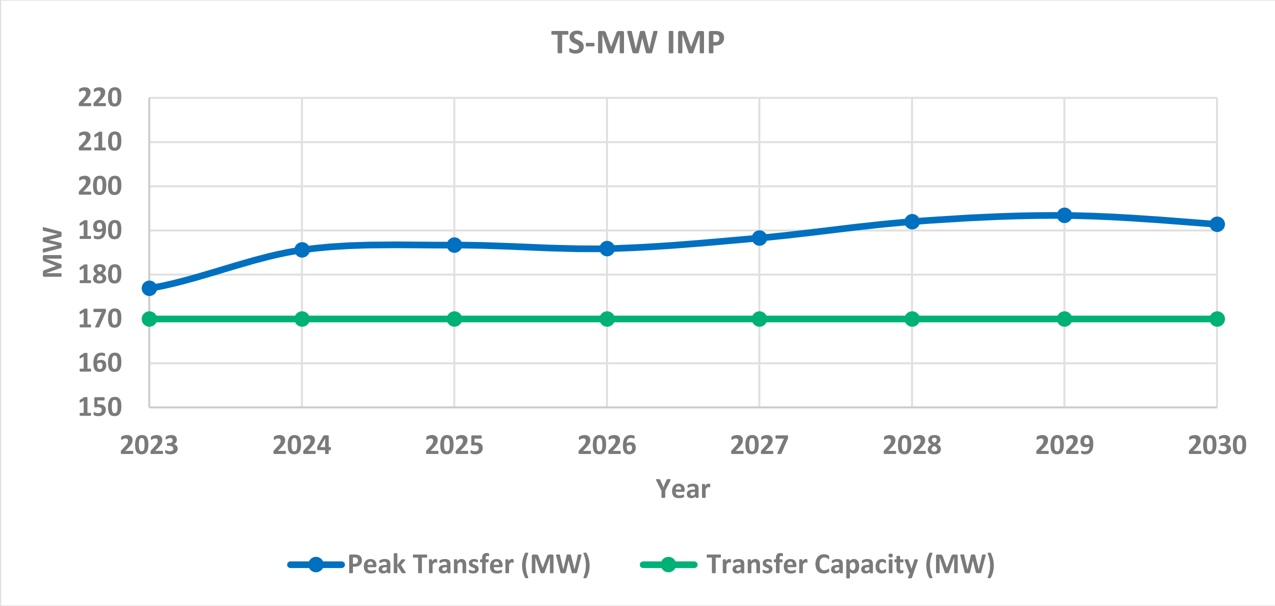

Figure 17: Expected transfer and transfer capacity in TS-MW IMP boundary – peak demand

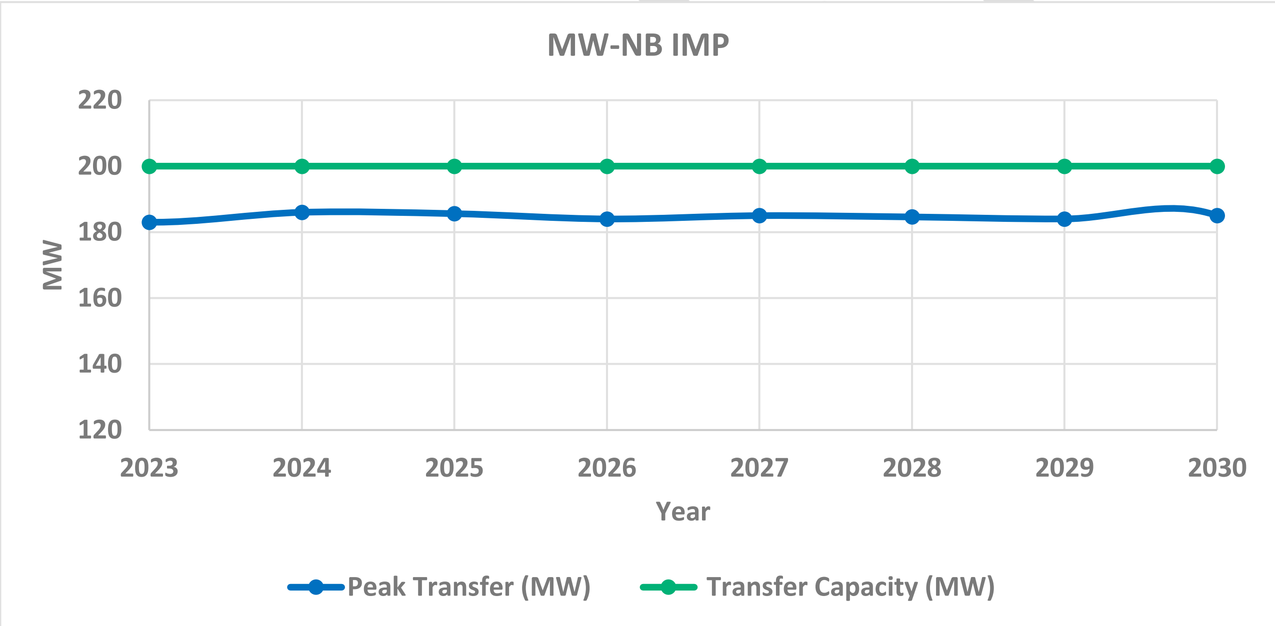

Figure 18: Expected transfer and transfer capacity in MW-NB IMP boundary – peak demand

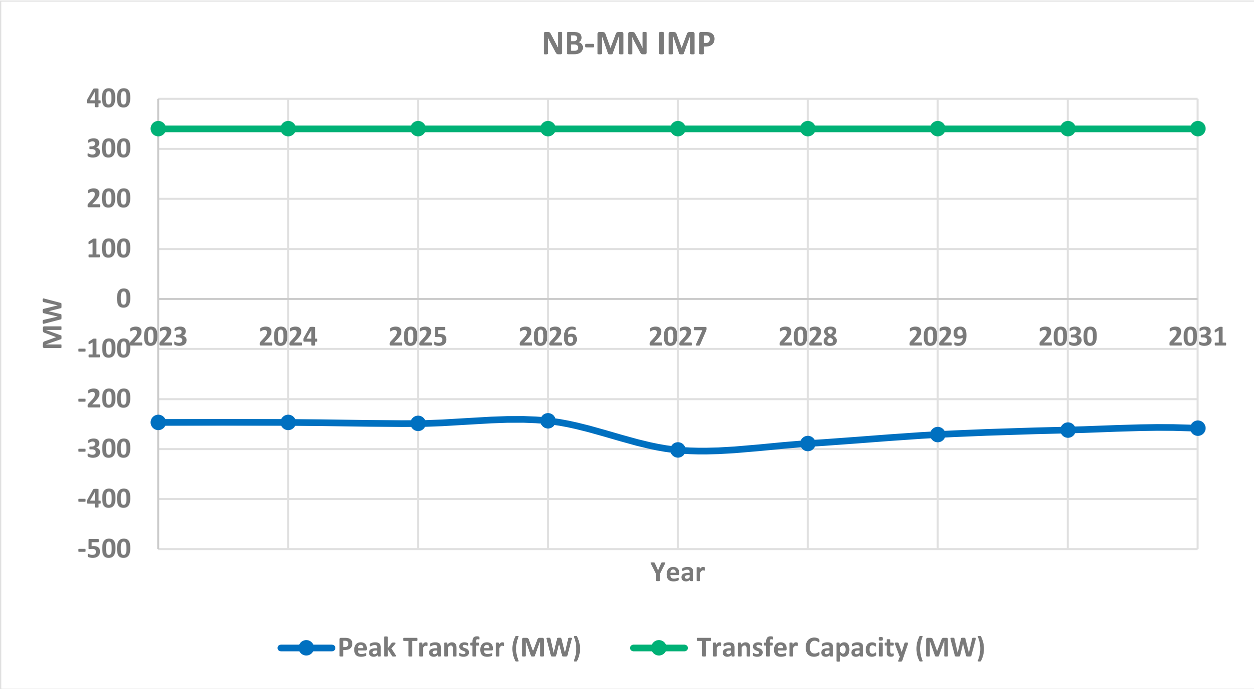

Figure 19: Expected transfer and transfer capacity in NB-MN IMP boundary – peak demand

The above figures illustrate that there is no available import capacity within the TS-MW import boundary, due to limitations on the 132 kV network. In addition, there is limited available import capacity across the remaining NC-TS, MW-NB boundaries during the study period. Despite available capacity being observed within the NB-MN boundary, this is limited to new loads that are installed between the NB-MN and MW-NB boundaries otherwise the transfer capacities within the subset boundaries may be exceeded.

Export Boundaries

Figure 20 highlights the network export boundaries in the North Region. These boundaries are defined using the worst contingency (⚡) and the worst overload circuit (*) as shown in **Table 4**.

The expected transfer and transfer capacity for each of the import boundaries across the study period are shown in **Figure 21** to **Figure 24**.

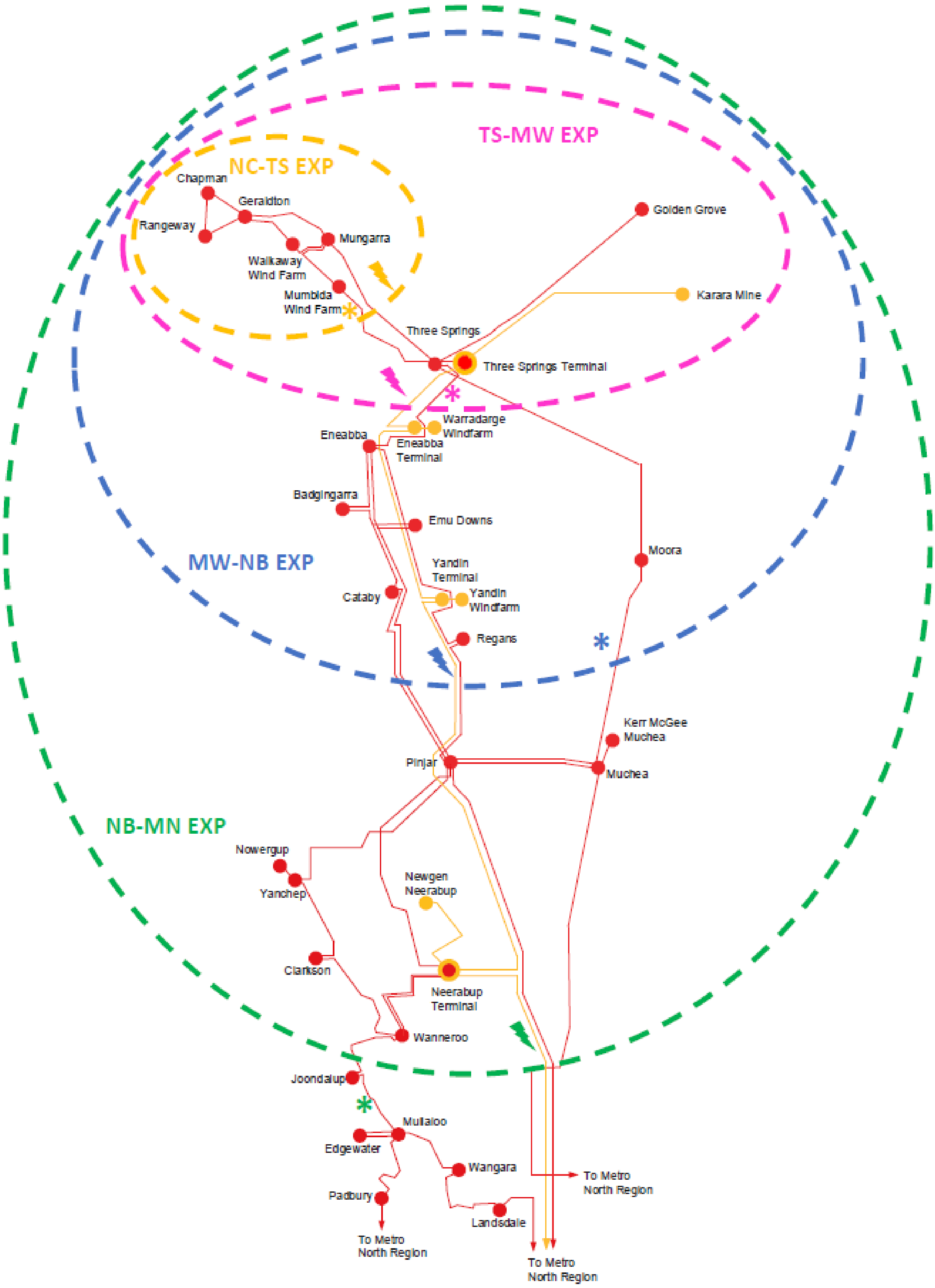

Figure 20: Network thermal export boundaries in the North Region

Table 4: Thermal export boundaries characteristics – North Region

Characteristics	Export Boundaries			
	NC-TS EXP	TS-MW EXP	MW-NB EXP	NB-MN EXP
Worst contingency	Three Springs to Mungarra 132 kV line	Eneabba Terminal to Three Springs Terminal 330 kV line	Neerabup Terminal to Yandin Terminal 330 kV line	Northern Terminal to Neerabup Terminal 330 kV line
Contingency type	N-1	N-1	N-1	N-1
Worst circuit	Three Springs to Mumbida 132 kV line	Eneabba to Three Springs 132 kV line	Muchea to Moora 132 kV line	Henley Brook to Muchea 132 kV line

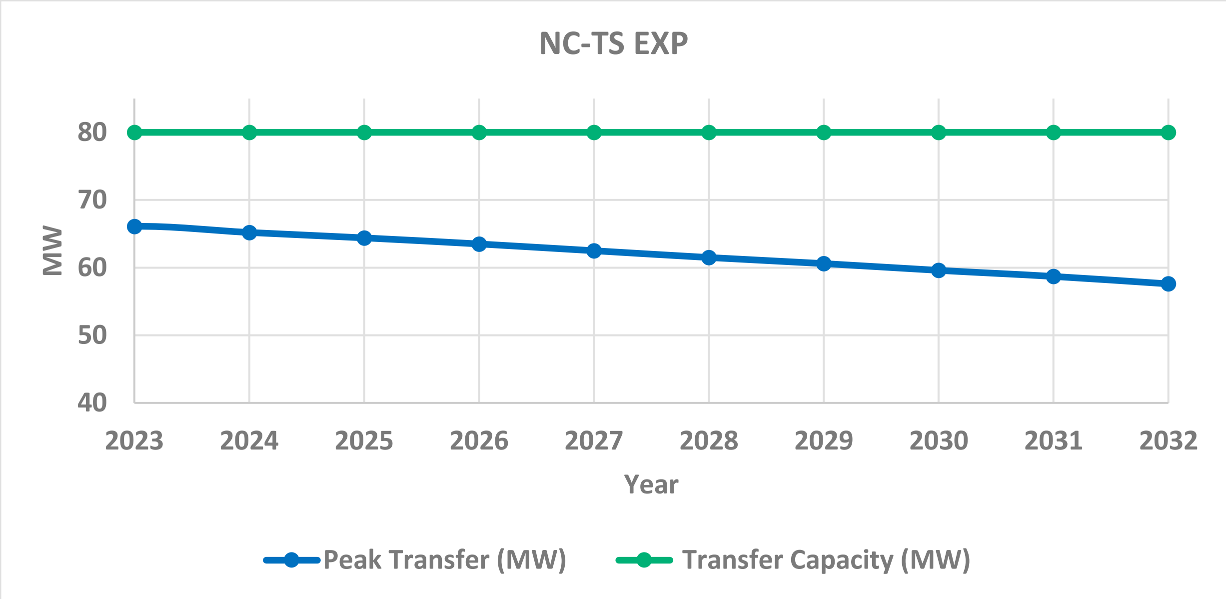

Figure 21: Expected transfer and transfer capacity in NC-TS EXP boundary – peak demand

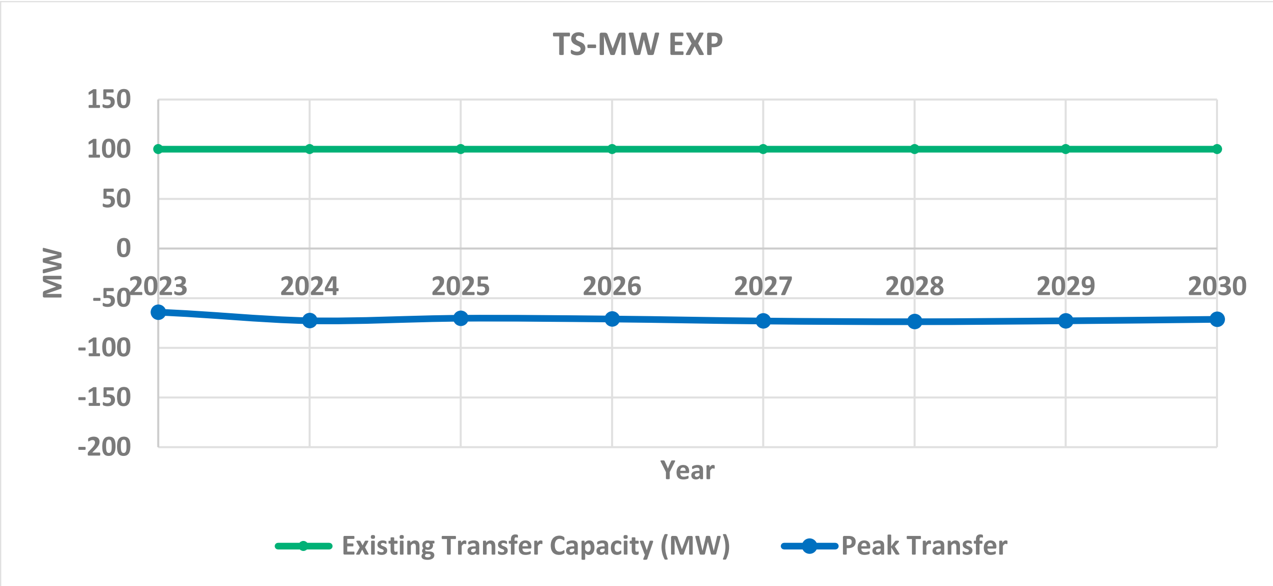

Figure 22: Expected transfer and transfer capacity in TS-MW EXP – peak demand

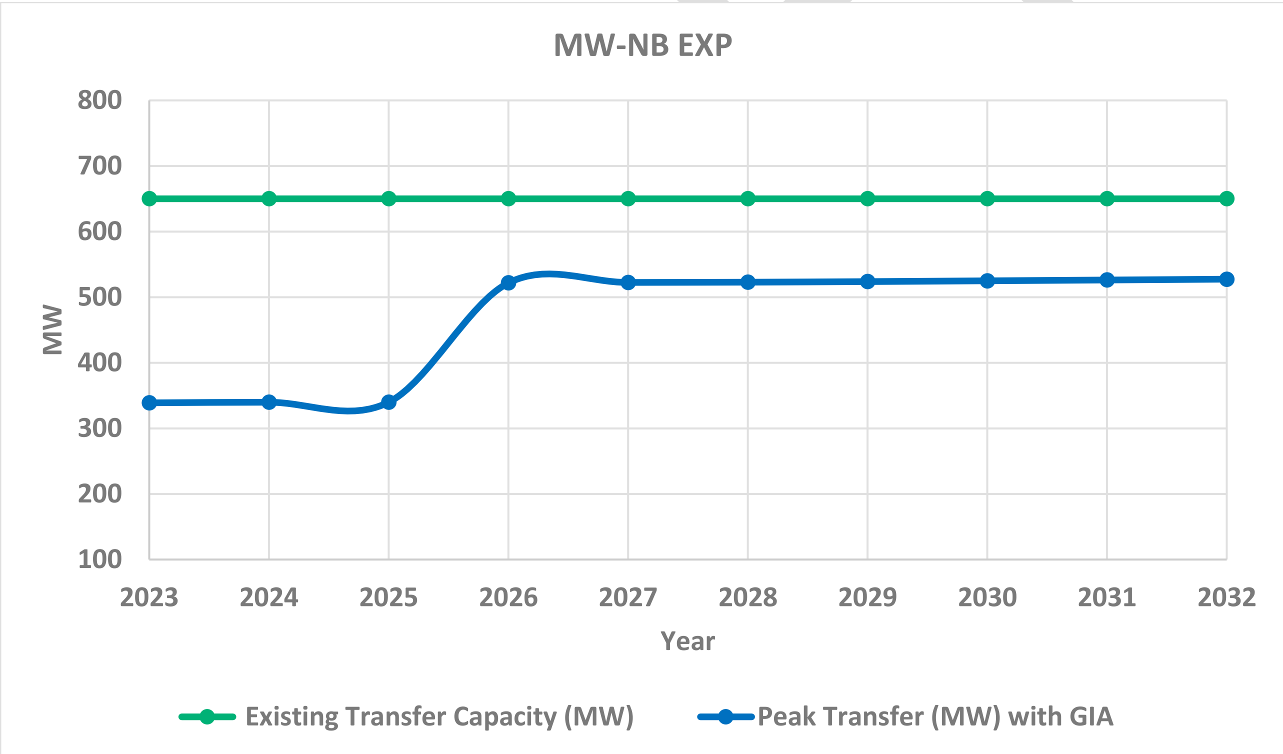

Figure 23: Expected transfer and transfer capacity in MW-NB EXP boundary – peak demand

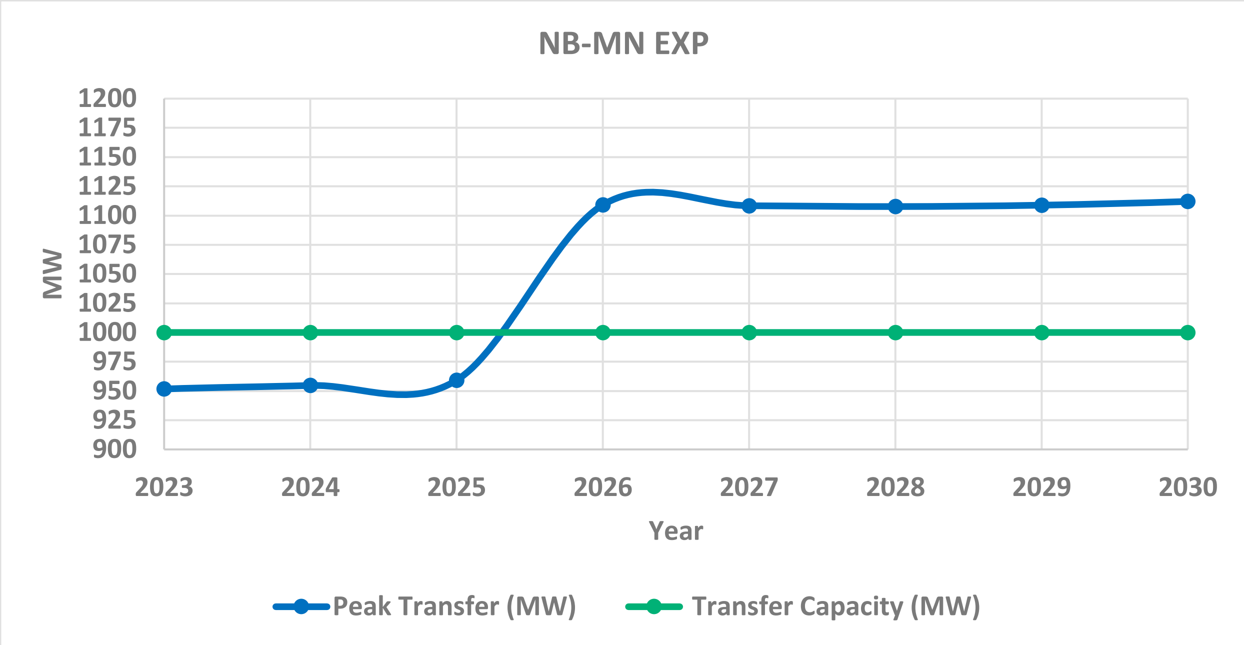

Figure 24: Expected transfer and transfer capacity in NB-MN EXP boundary – peak demand

The above figures illustrate that new generation connection for the NC-TS and MW-NB boundaries are very limited and hence the proposed network augmentation under development to provide additional capacity. The export capacity through NB-MN boundary is predicted to be exceeded with the connection of large new scale generators. With abundant renewable fuel resources in the area, new generation connections are likely to increase congestion issues within this region prior to the completion of the network augmentations. Following the completion of the proposed North Region Stage 1 works (see section 3.5.2) the NB-MN Exp transfer capacity is expected to increase by 50%.

The power flows in TS-MW are negative, indicating that this boundary is a net importer of power during high generation and peak demand conditions.

10.3.2 Thermal Constraints - Transmission Lines

A number of post contingent thermal overloads arise within the North Region during peak conditions and under certain dispatch scenarios. For example:

- Existing 132 kV Three Springs Substation busbar overloads exist, following the loss of the Three Springs to Three Springs Terminal 132 kV and Three Springs to Eneabba Terminal 330 kV circuits (N-1-1), during both peak and minimum demand conditions when renewable generation output is high[27].
- Neerabup Terminal to Wanneroo 132 kV line, Joondalup to Wanneroo 132kV line and Joondalup to Mullaloo 132kV line overloads occur by 2022/23 and increases up to 108 per cent, following the loss of the Northern Terminal Transformer 2 in peak demand conditions.

[27] These constraints are managed by post-contingent generation runback schemes that are designed to curtail the intermittent generation in the area to prevent network security related issues.

Western Power currently manages these thermal constraints through operational measures including special protection schemes[28] and taking the Neerabup Terminal 330/132 kV transformer out of service under certain operating conditions[29]:

- Mullaloo to Joondalup 132 kV line overloads occur by 20/21 and increases up to 104 per cent, following the loss of the Northern Terminal to Pinjar 132 kV line
- Neerabup Terminal to Wanneroo 132 kV line overloads occur by 20/21 and increases up to 104 per cent, following the loss of the Clarkson to Yanchep 132 kV line
- Neerabup Terminal to Wanneroo 132 kV line overloads occur by 20/21 and increases up to 114 per cent, following the loss of the Pinjar to Yanchep 132 kV line
- Pinjar to Muchea 132 kV line 82 overloads occur by 22/23 and increases up to 110 per cent, following the loss of the Pinjar to Muchea 132 kV line 81
- Pinjar to Yanchep 132 kV line overloads occur by 22/23 and increases up to 111 per cent, following the loss of the Neerabup Terminal to Wanneroo 132 kV line
- Yanchep to Clarkson 132 kV line overloads occur by 22/23 and increases up to 106 per cent, following the loss of the Neerabup Terminal to Wanneroo 132 kV line
- Muchea to Henley Brook 132 kV line overloads occur by 22/23 and increases up to 103 per cent, following the loss of the Joondalup to Wanneroo 132 kV line.

10.3.3 Thermal Capacity – Transformers

This section shows existing utilisation and forecast peak load utilisation across the period 2023/24 to 2032/33 for all zone substations operated by Western Power within the North Region. **Table 6** highlights the different substation utilisation classifications. As substations become highly utilised Western Power will typically investigate and develop cost-effective options to alleviate a potential capacity constraint. Network solutions range from network switching, distribution transfers to neighbouring under-utilised substations and substation transformer capacity upgrades. Non-network options, such as demand-side management solutions are also considered.

As utilisation levels increase towards being over utilised, proposed network plans develop into projects. Western Power also develops contingency plans to minimise the associated risks of a transformer failure prior to completion of a project.

Table 5: Utilisation legend (for Table 6)

LEGEND	Classification Name	Utilisation %
	Under utilised	below 40%
	Medium utilisation	>40% & 75%
	Highly utilised	>75% & 95%
	Over utilised	above 95%

[28] Details of Special Protection Schemes have been shared with AEMO for operation of the system.

[29] Removal of the Neerabup Terminal transformer during high wind output conditions can increase the size of the largest single contingency, which presents increased risks to maintaining frequency stability.

Table 6: North Region: Zone Substation utilisation heat map

	Capacity	Actual Utilisation (%)	Forecast Utilisation (%)																				Mitigation
Substation	Current MVA	2022	2024		2025		2026		2027		2028		2029		2030		2031		2032		2033		
			POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	
Clarkson[30]	56	72	130	64	124	61	123	61	130	65	140	70	147	74	152	76	152	77	156	79	165	84	Additional transformer (Scoping, estimated in service by FY2025/26)
Chapman	31	14	48	13	48	13	48	13	48	14	50	14	50	14	51	14	52	15	53	15	54	15	
Eneabba	31	31	37	11	37	11	38	11	39	12	40	12	41	12	43	13	44	13	45	13	46	14	
Geraldton	65	45	59	33	59	33	59	33	59	33	59	33	60	33	60	34	60	34	60	34	61	34	
Joondalup[31]	53	102	99	47	100	47	100	47	101	48	102	48	104	49	105	50	106	50	108	51	110	52	Managed by distribution transfers. Additional transformer option (Initiation by FY2032/33)
Landsdale	88	89	97	76	98	76	98	77	100	79	102	81	104	82	105	84	106	86	109	87	112	90	Managed by distribution transfers
Moora	16	89	111	71	111	72	112	73	112	75	112	77	113	79	113	80	114	81	114	84	115	84	Managed by distribution transfers
Muchea	51	52	58	16	58	16	58	16	60	16	61	16	63	16	64	16	65	16	66	17	68	17	
Mullaloo	66	78	76	28	76	27	75	28	74	29	74	29	74	30	73	31	73	31	72	32	72	33	
Padbury	82	80	91	68	90	66	89	65	89	66	92	68	94	69	95	70	95	70	95	70	97	72	
Rangeway	69	51	44	34	46	35	47	35	48	36	49	37	50	38	51	39	53	40	54	41	55	42	
Regans 22 kV	19	55	60	11	60	11	62	11	63	11	63	12	64	12	66	12	67	12	69	13	70	13	
Regans 33 kV	19	73	68	10	68	10	69	10	69	10	69	11	69	11	69	11	70	11	70	11	70	11	
Three Springs	16	54	72	10	73	10	73	10	73	10	72	10	72	10	71	10	72	10	72	10	72	10	
Wangara	28	73	98	83	100	85	102	86	103	87	104	88	105	90	107	91	108	93	110	94	111	96	Managed by distribution transfers
Wanneroo	84	60	98	74	101	77	103	78	104	79	105	80	107	81	109	83	111	85	114	87	116	89	Managed by distribution transfers
Yanchep	70	69	74	49	72	48	71	48	72	49	74	50	75	51	77	53	78	54	80	55	82	57	

30 Western Power is developing contingency plans to manage the substation capacity shortfall risks prior to the installation of an additional transformer

10.3.4 Steady State Voltages

Voltage related performance constraints within the North Region arise during peak demand conditions over the study period, including:

- Low voltages (0.8pu) by 2022/2023at the Three Springs Terminal 330 kV busbar, following the loss of the Eneabba Terminal to Three Springs Terminal 330 kV line.

Voltage related performance constraints also arise within the North Region during minimum demand conditions over the study period, including:

- High voltages (1.09 pu) and excessive voltage step conditions (+8-9 per cent) arise by 2025/26 at the Chapman, Geraldton, Mumbida, Rangeway and Walkaway 132 kV busbars, following the loss of the Three Springs Terminal to Three Springs 132 kV line.

10.3.5 Fault Levels

There are no fault level related performance constraints within the North Region over the study period.

10.3.6 Stability

Due to the growing levels of inverter-based generation in the North Region, Western Power conducted N-0 system strength studies for all existing facilities in the region. The results observed that all facilities are expected to retain control loop stability.

Though the existing N-0 studies have not revealed any system strength limitations, given the limited number of synchronous generators in parts of the networks, Western Power expects that system strength issues will materialise under certain contingency conditions. Solutions to these issues could include retuning of the control parameters of a facility, installation of stabilising equipment (e.g., BESS, STATCOM, synchronous condensers) or operational constraints.

Further work is ongoing to refine the EMT models and undertake system studies for contingency conditions in the North Region.

10.3.7 Reliability

Although designed and operated to a N-1 standard, lower levels of historical reliability performance with the aged and older construction standard 132 kV transmission lines from Three Springs Zone Substation to Mumbida and Mungarra plus prolonged outage times have triggered the need for Western Power to procure a Network Control Service with Synergy. This service is designed to enable the 132 kV network north of the Three Springs Zone Substation to operate as an island, following the loss of both 132 kV transmission lines[31] from Three Spring. Historical and future performance is shown in **Figure 25**.

[31] A large portion of these 132kV circuits is built with legacy "cricket wicket' structures that are more prone to failure in strong wind conditions.

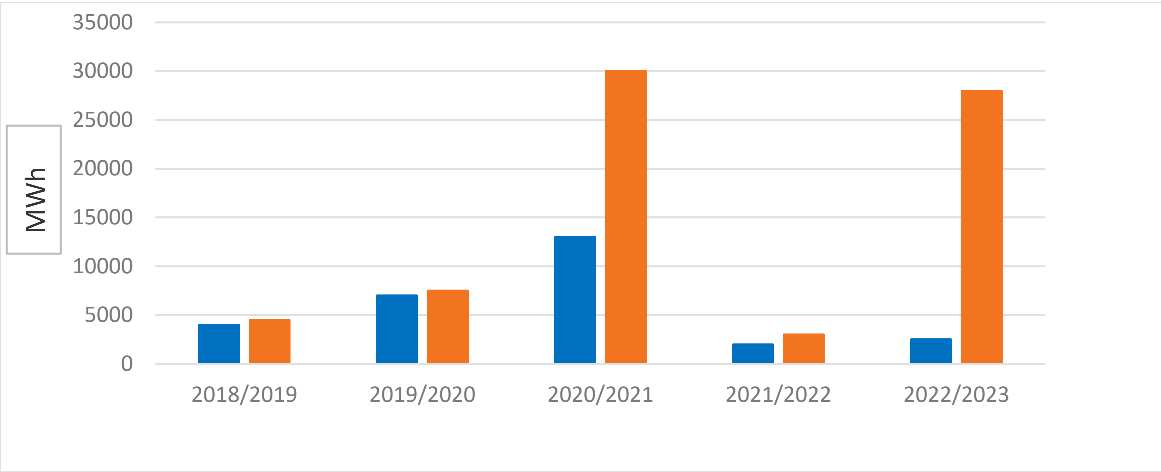

Figure 25: NCS operation in the North Region

10.3.8 Asset

Existing asset performance constraints were identified in the North Region within the study period, including:

- A number of zone and terminal substation transformers in degraded condition require mitigation within the study period, including:
    - Geraldton– 132/22 kV, 33 MVA - T1 and T3
    - Regans– 33/22 kV, 15 MVA – T4
    - Three Springs– 132/33 kV, 13 MVA – T1 and T3
- One of the 11 kV switchboards at Chapman Substation is in degraded condition and needs to be addressed in the next 10 years.
- A large portion of the assets on the 132 kV transmission line from the Three Springs Zone Substation to Mungarra are in degraded condition and need to be addressed within the study period. Western Power is currently investigating replacement plans, including options to increase capacity to accommodate future demand and customer connections in the area.

10.4 Network Augmentation Works

Completed, committed, and proposed transmission projects in the North Region are shown in **Table 7**.

Table 7: Completed, committed, and proposed projects - North Region

Project	Scope	Benefits of project	Network driver/s	By when	Lifecycle Status
Geraldton Substation: 33 kV switchyard asset replacement	Replace 33 kV switchyard assets at Geraldton Zone Substation	Address degraded asset condition issues	Asset condition	FY2023/24	Execution
Clarkson Substation: Additional transformer	Installation of a third 132/22 kV 33 MVA transformers at Clarkson Substation.	Address existing substation capacity shortfall and accommodating increase demand in the area	Growth - Thermal	FY2025/26	Scoping
Neerabup special protection scheme	Opens 132kV circuit breaker following contingency to manage capacity shortfall in Neerabup area	Address capacity shortfall	Growth – Thermal	FY2023/24	Execution

10.5 Network Opportunities

This section highlights possible network opportunities & network solutions in the North Region over the study period. These opportunities will be explored further during the scoping and planning phases of the project lifecycle. If the opportunities are not a technically and economically viable, network solutions will be implemented to address the identified network constraints.

Table 8: Network Opportunities projects - North Region

Location	Scope/Issue	Market Opportunity	By when	Lifecycle Status	Proposed Network Solution
Joondalup Substation	Demand growth and substation transformers overloading	Reduce the demand supplied by Joondalup Substation during peak demand conditions to potentially reduce or defer network augmentation to increase the power transfer capacity to the area.	FY2032/33	Initiation	Installation of a third 132/22 kV 33 MVA transformer
MW-NB and NB-MN available import capacity	Spare available import capacity exists over a number of import boundaries within the North Region.	An opportunity exists to utilise spare available capacity within MW-NB and NB-MN import boundaries by increasing demand of existing loads or via the connection of new loads	Across the study period	N/A	N/A
TS-MW and MW-NB available export capacity	Spare available export capacity exists over a number of export boundaries within the North Region.	An opportunity exists to utilise spare available capacity within the TS-MW and MW-NB export boundaries by connecting new generation.	Across the study period	N/A	N/A

10.6 Emerging Issues and Drivers

Despite existing thermal capacity limitations in the North Region network, there is still limited spare capacity across parts of the region, as described in section 10.5. In the short term, connection under the constrained network access model will provide prospective generators a flexible option ahead of future capacity projects.

Over the medium to longer term, the combination of relatively high availability of land and local wind and solar fuel resources mean the region has the potential to become a significant exporter of energy. This is likely to increase the congestion issues within the region and drive network augmentations. To provide additional bulk power transfer capacity from the North Region into the Perth Metro area.

Over the longer term, electrification of industries and decarbonisation developments are also expected to drive significant increases in import and export transfer capacity in the North Region, including potential large-scale renewable, storage infrastructure and green hydrogen production facilities.

Following the completion of the proposed North Region Stage 1 works the network import and export capacity between Metro North and the Mid-West by circa 100%.

11. South Region

11.1 Geography

The South Region covers the Great Southern and Southern West part of the Western Power transmission network. The west part of this region covers from Alcoa Pinjarra in the north to Augusta in south. The east part of the region extends from Muja Power Station to Manjimup and Beenup in the south-west, Albany to the south- east, Boddington to the north and Narrogin in the north-east.

Figure 26 shows the transmission system in this region.

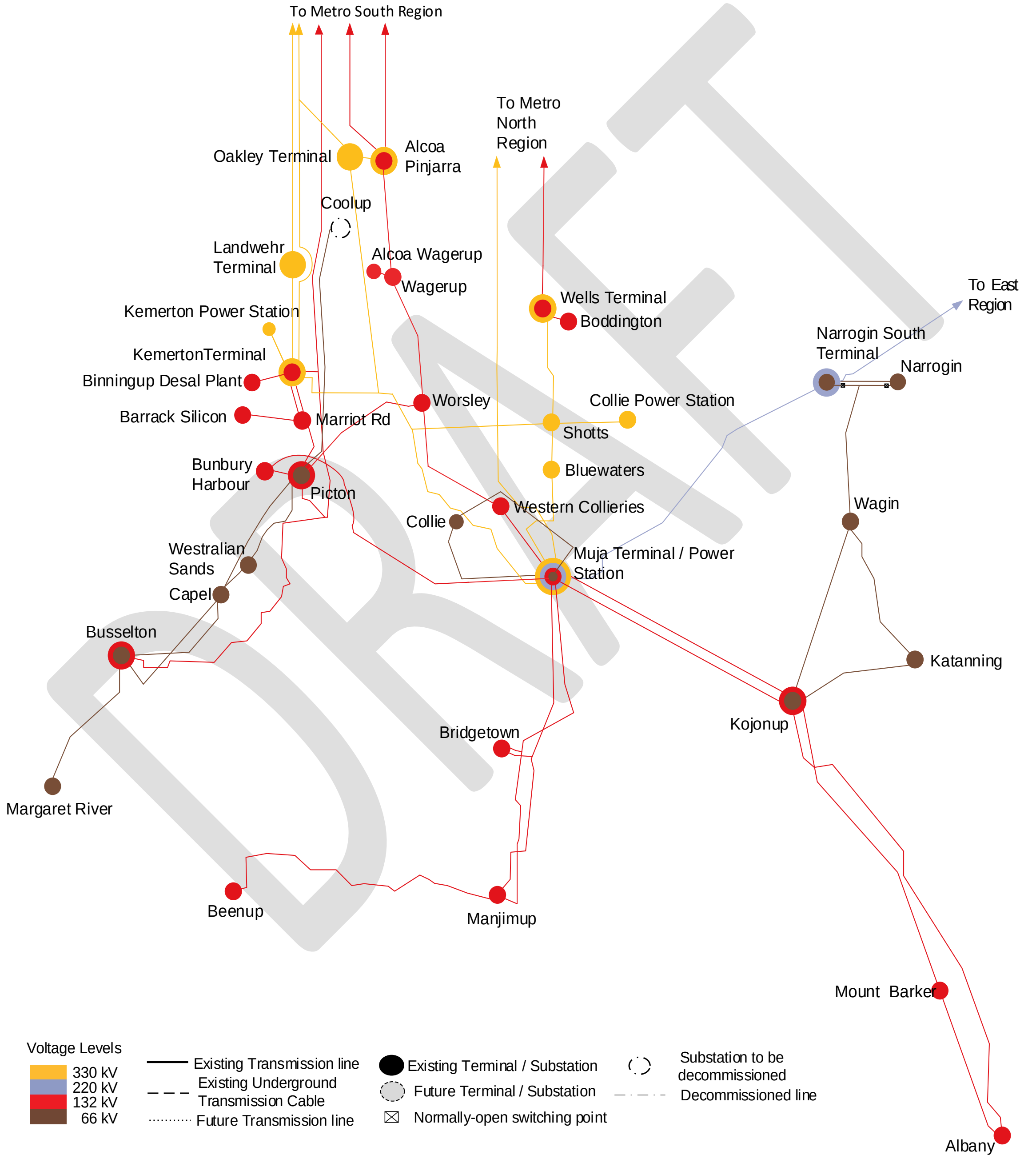

Figure 26: Western Power's South Region – Network Diagram

The South Region has 10 terminal stations and 18 zone substations that are owned and operated by Western Power. The other transmission sites in the region are customer owned substations.

Terminal substations

- Bluewater Terminal – 330 kV
- Busselton Terminal – 132/66 kV
- Kemerton Terminal – 330/132 kV
- Kojonup Terminal – 132/66 kV
- Landwehr Terminal – 330 kV
- Muja Terminal – 330/220/132/66 kV
- Narrogin South Terminal – 220/66 kV
- Oakley Terminal – 330 kV
- Picton Terminal – 132/66 kV
- Shotts Terminal – 330 kV
- Wells Terminal – 330/132 kV

Zone Substations / WP Substations

- Albany – 132/22 kV
- Beenup – 132/22 kV
- Bridgetown – 132/22 kV
- Bunbury Harbour – 132/22 kV
- Busselton – 132/66/22 kV
- Capel – 66/22 kV
- Collie – 66/22 kV
- *Coolup – 66/22 kV*[32]
- Katanning – 66/22 kV
- Kojonup –66/22 kV
- Margaret River – 66/22 kV
- Marriott Road – 132/22 kV
- Mount Barker – 132/22 kV
- Manjimup – 132/22 kV
- Narrogin – 220/66/22 kV
- Picton – 66/22 kV
- Wagerup – 132/22 kV
- Wagin – 66/22 kV

Customer Substations

- Alcoa Pinjarra – 132 kV
- Alcoa Wagerup – 132 kV
- Collie Power Station – 330 kV
- Binningup Desalination Plant – 132 kV
- Bluewaters Power Station – 330 kV
- Boddington – 132 kV
- Kemerton Power Station – 330 kV
- Wagerup – 330 kV
- Western Collieries – 132 kV
- Westralian Sands – 66 kV

11.2 Regional Characteristics

11.2.1 General

The South Region is comprised of residential, industrial, and farming loads. It is also a generation hub of conventional (mostly coal-fired) generation.

Due to the extensive geographical spread of the South Region, its substations supply peak demands at different periods in a year. The substations supplying mostly residential loads are winter peaking, while majority of the substations supplying predominantly agricultural loads have a summer peak pattern.

[32] Coolup 66 kV substation was decommissioned in late 2022.

Underpinned by tourism, coastal lifestyle seekers and industrial and mining developments, the growing concentration of urban development in Bunbury and Busselton has seen similar pressures placed on the South Region system.

11.2.2 Generation

The generation portfolio in this region is predominately coal. Most of the coal-fired generation is concentrated at Muja and Collie, about 200km south of Perth. Synergy currently owns and operates both power stations, which have an aggregate capacity of approximately 1,200 MW.

On 14 June 2022, the State Government announced plans to progressively retire all remaining State-owned coal-fired power stations by 2030. These exits will leave only one coal-fired power plant operating in WA – the privately-owned Bluewaters generator, which is also near Collie.

The retirement of coal-fired generation in the South Region represents a fundamental change in voltage control and performance, both within the region and in the wider SWIS, as well as reducing overall system inertia and strength. This is offset to some extent by development of several large battery energy storage projects which are planned in the region.

The Bunbury and Picton South area is supplied by local generation at Kemerton and relies heavily on generation from the Muja area. Apart from coal-fired generation, the South Region consists of wind power generation mainly concentrated around Albany.

11.2.3 Existing Transmission Network Supply

The South Region has a mix of 330 kV, 220 kV, 132 kV and 66 kV transmission voltages with relatively long transmission lines compared to most of other regions. The region has a strong 330 kV network including long transmission lines from the Muja and Kemerton terminal substations. There is also a single 220 kV transmission line from the Muja terminal that supplies the Narrogin South terminal and continues to the Eastern Goldfields, as well as several 132 kV sub-transmission systems connecting to the Picton, Bunbury and Busselton substations.

Given the availability of fuel resources, particularly coal, the area has historically been home to the bulk of base load generating capacity via the bulk 330 kV transmission network. The security and reliability of the network surrounding the Muja Terminal is paramount because of the reliance of neighbouring regions on the generation capacity connected to it. The area itself is divided into a number of independent sub-networks supplying load connected via 132 kV and 66 kV transmission lines. A significant portion of the 66 kV transmission network was built to a 132 kV standard, which presents opportunities to either convert it to 132 kV or retire the network as these assets reach the end of their service life.

The bulk of supply to support demand in the region south of Kemerton comes from the Muja and Kemerton terminals via several 132 kV transmission lines. Power is transferred to the Kemerton terminal at 330 kV from the Muja terminal, as well as from other 330 kV terminals.

Customer demand south of Picton - including demand at Busselton, Capel and Margaret River - represents a considerable portion of the total demand in the load area. This is supplied by a single 132 kV circuit which interconnects Picton, Kemerton, Pinjarra and Busselton and the ageing and voltage constrained 66 kV transmission network that extends from Picton as far south as Margaret River.

11.2.4 Key Developments in the Region

Key developments in the South Region have been focused on the increasing challenges associated within operating base load generation, due to the overwhelming uptake in residential rooftop solar. There is a continued interest in large scale battery storage and renewable generation projects in the region.

11.3 Performance

This section presents the network performance for the South Region over the study period.

11.3.1 Thermal Capacity - Boundaries

The following assumptions were made in developing the import and export boundaries:

- Import boundaries consider peak demand and security constrained and economic dispatch conditions.
- Export boundaries consider peak demand and maximum generation dispatch conditions (within boundary).

Import Boundaries

Figure 27 shows the network import boundaries in the South Region. These boundaries are defined using the worst contingency (↯) and the worst overload circuit (*) as shown in **Table 9**.

The expected transfer and transfer capacity for each of the import boundaries across the study period are shown in **Figure 28** to **Figure 31**.

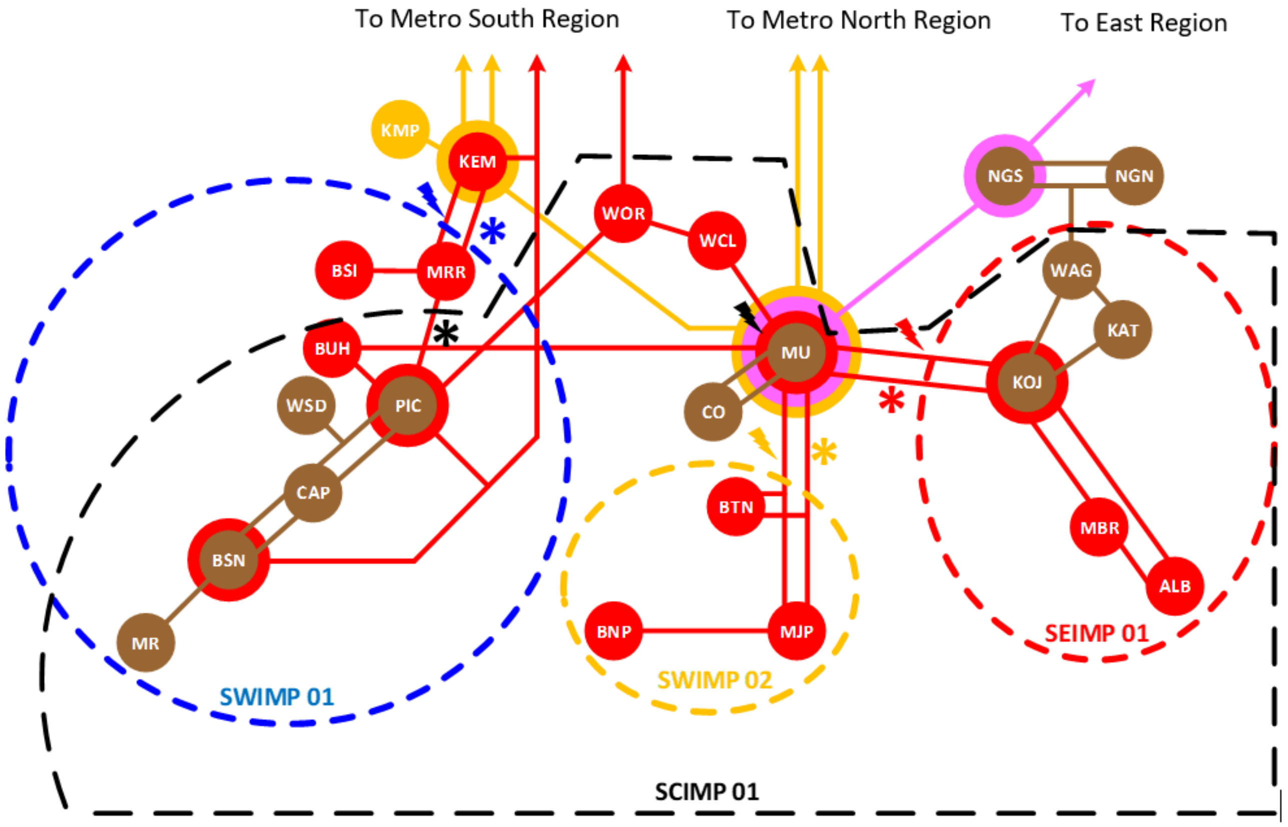

Figure 27: Network import boundaries in the South Region

Table 9: Thermal import boundaries characteristics – South Region

Characteristics	Import Boundaries			
	SWIMP 01	**SWIMP 02**	**SEIMP 01**	**SCIMP 01**
Worst contingency	Kemerton – Marriot Road 81 or Kemerton – Marriot Road 82	Muja-Manjimup/ Bridgetown 81 or Muja-Manjimup/Bridgetown 82	Muja – Kojonup 82	Muja BTT1 and BTT2
Contingency type	N-1	N-1	N-1	N-1-1
Worst overload circuit	Kemerton – Marriot Road 82 or Kemerton – Marriot Road 81	Manjimup/ Bridgetown 82 or Manjimup/ Bridgetown 81	Muja – Kojonup 81	Picton-Marriot Road 81

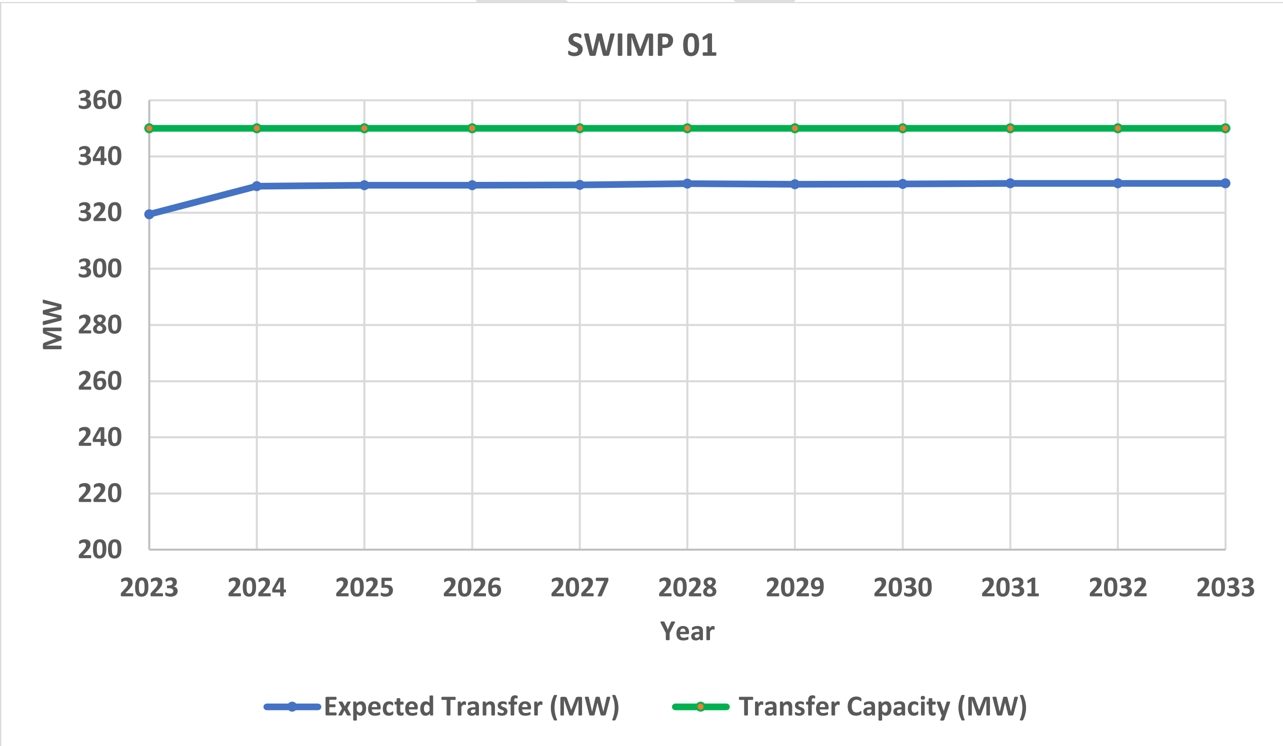

Figure 28: Expected transfer and transfer capacity in SWIMP 01 boundary – peak demand

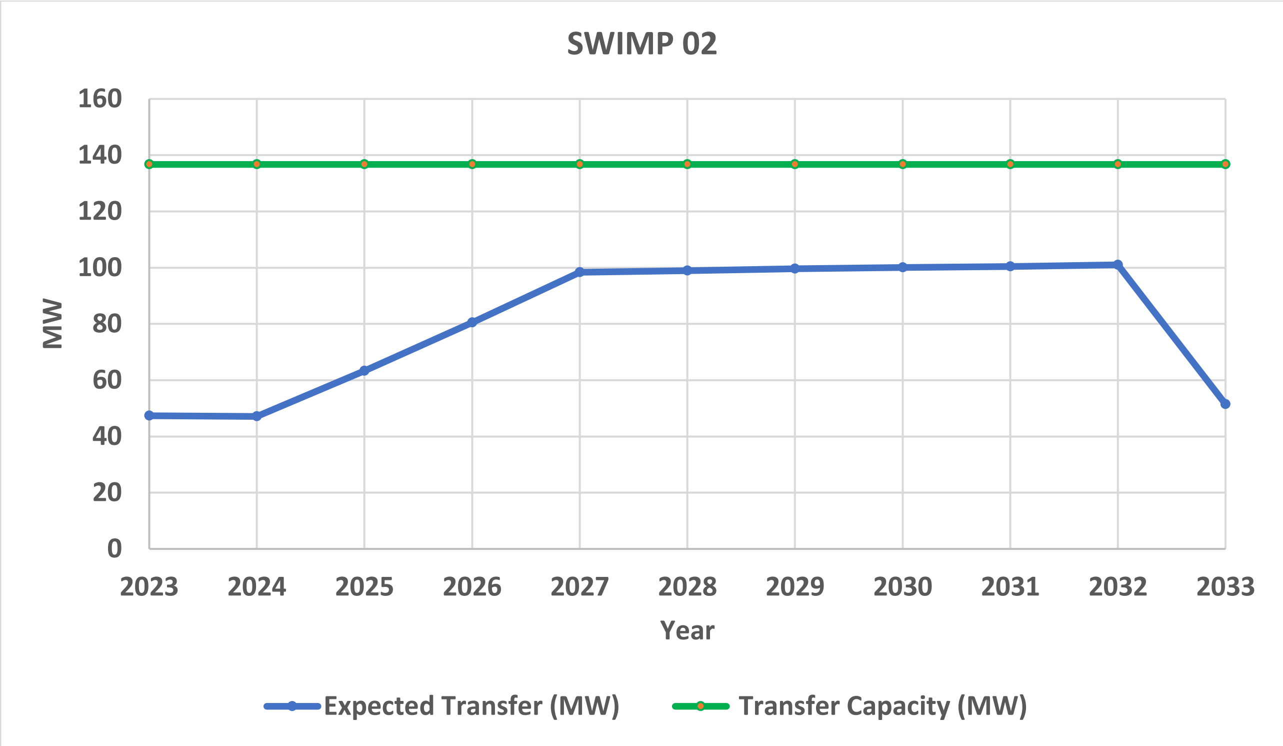

Figure 29: Expected transfer and transfer capacity in SWIMP 02 boundary – peak demand

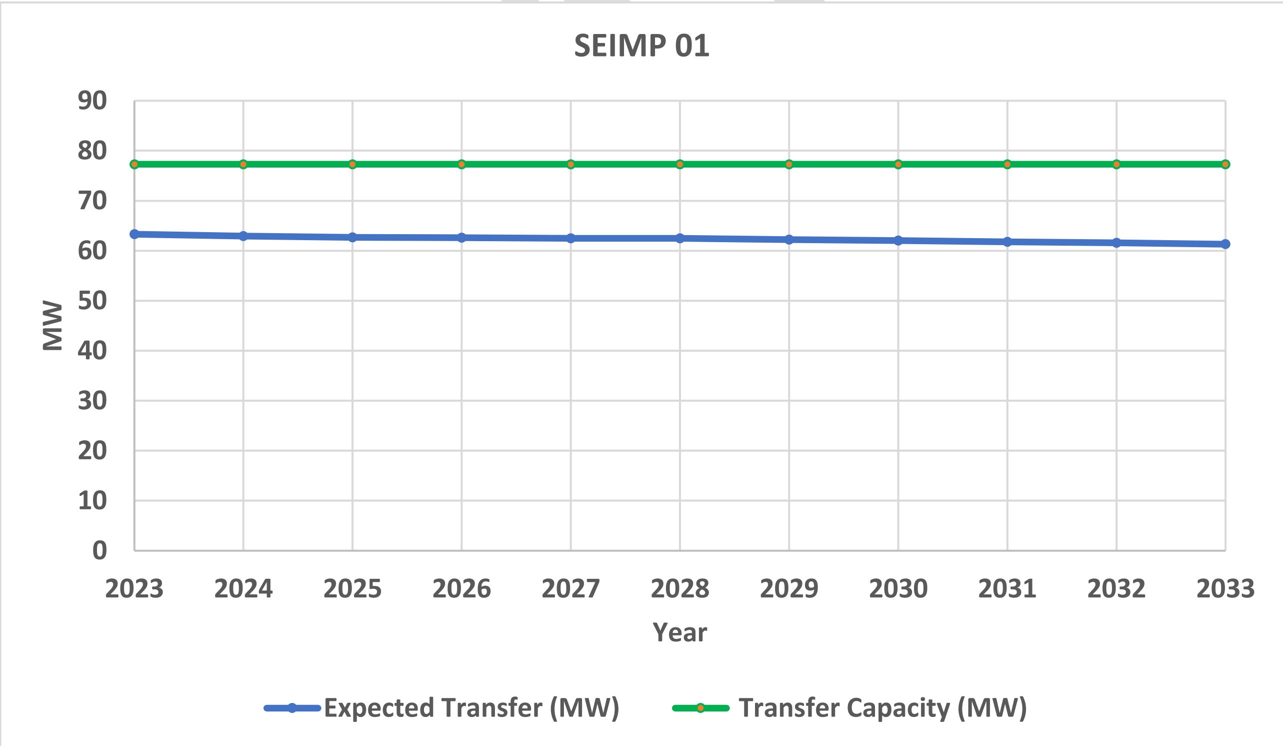

Figure 30: Expected transfer and transfer capacity in SEIMP 01 boundary – peak demand

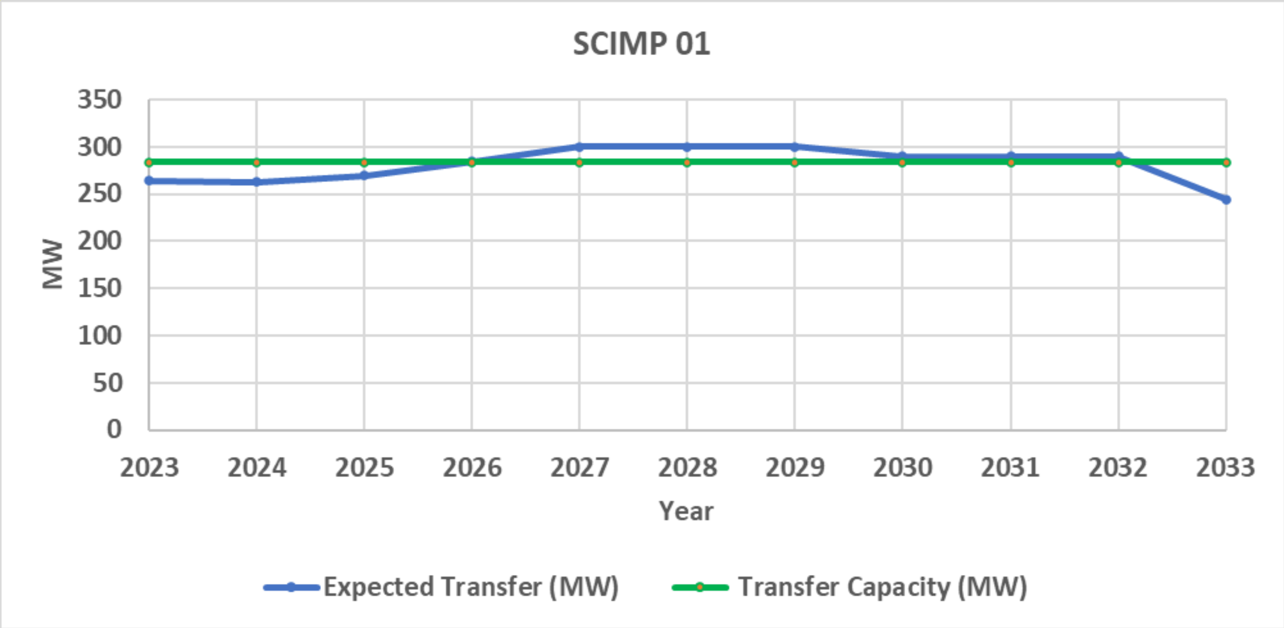

Figure 31: Expected transfer and transfer capacity in SCIMP 01 boundary – peak demand

As observed in the above figures, the available import capacity in SCIMP 01 is over the transfer capacity in 2026. This is a N-1-1 contingency due to the outage of both MU BTT1 & BTT2, which is a planned contingency outage at 80% of the expected peak load. This can be managed by careful selection of the planned outage period.

The available import capacity in SWIMP 02 is expected to be sufficient throughout the study period, whereas the connection of new loads within the SWIMP 01 and SEIMP 01 boundaries will be limited (15 – 20 MW) without network augmentation.

Export Boundaries

Figure 32 shows the network import boundaries in the South Region. These boundaries are defined using the worst contingency ( ) and the worst overload circuit (*) as shown in **Table 10**.

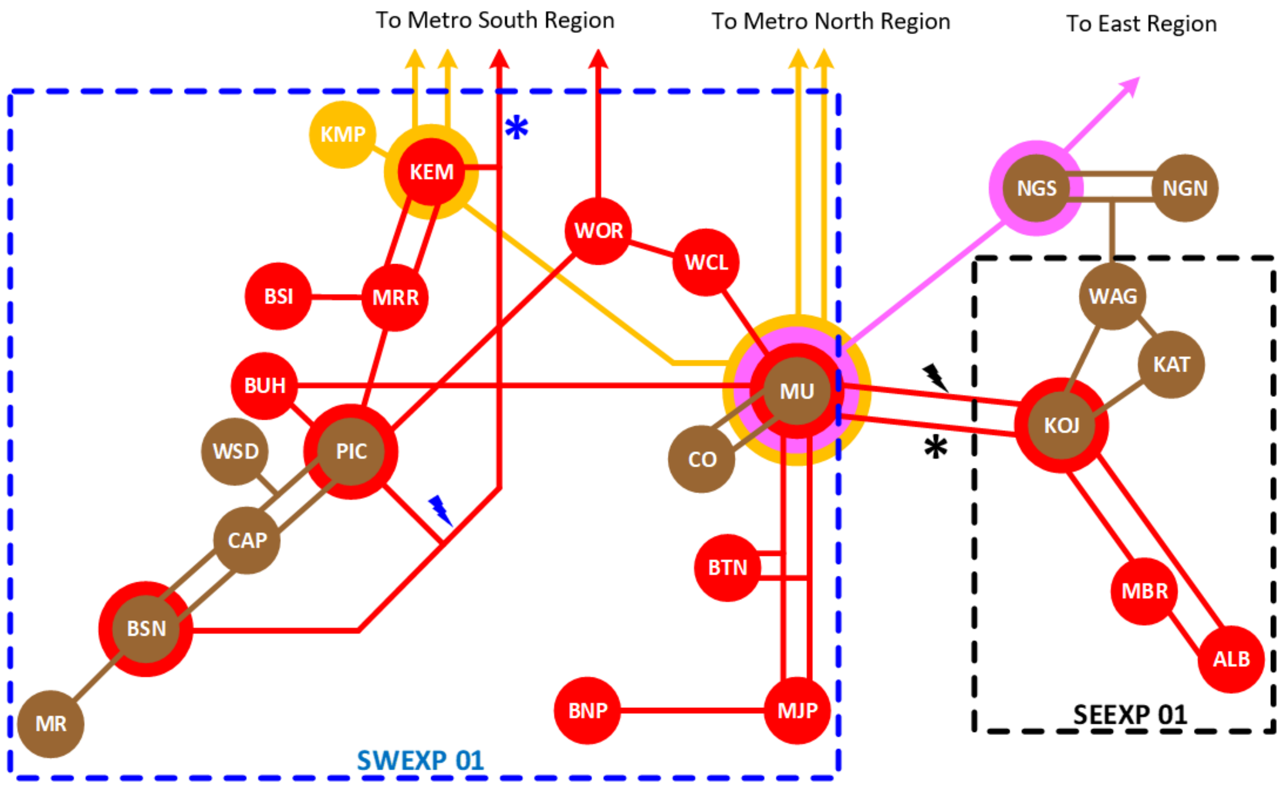

Figure 32: Network export boundaries in the South Region

Table 10: Thermal export boundaries characteristics – South Region

Characteristics	Export Boundaries	
	SWEXP 01	**SEEXP 01**
Worst contingency	Picton-Busselton 81	Muja-Kojonup 82
Contingency type	N-1	N-1
Worst overload circuit	Pinjarra-Alcoa Pinjarra 81	Muja-Kojonup 81

The expected transfer and transfer capacity for each of the import boundaries across the study period is shown in **Figure 33** and **Figure 34**.

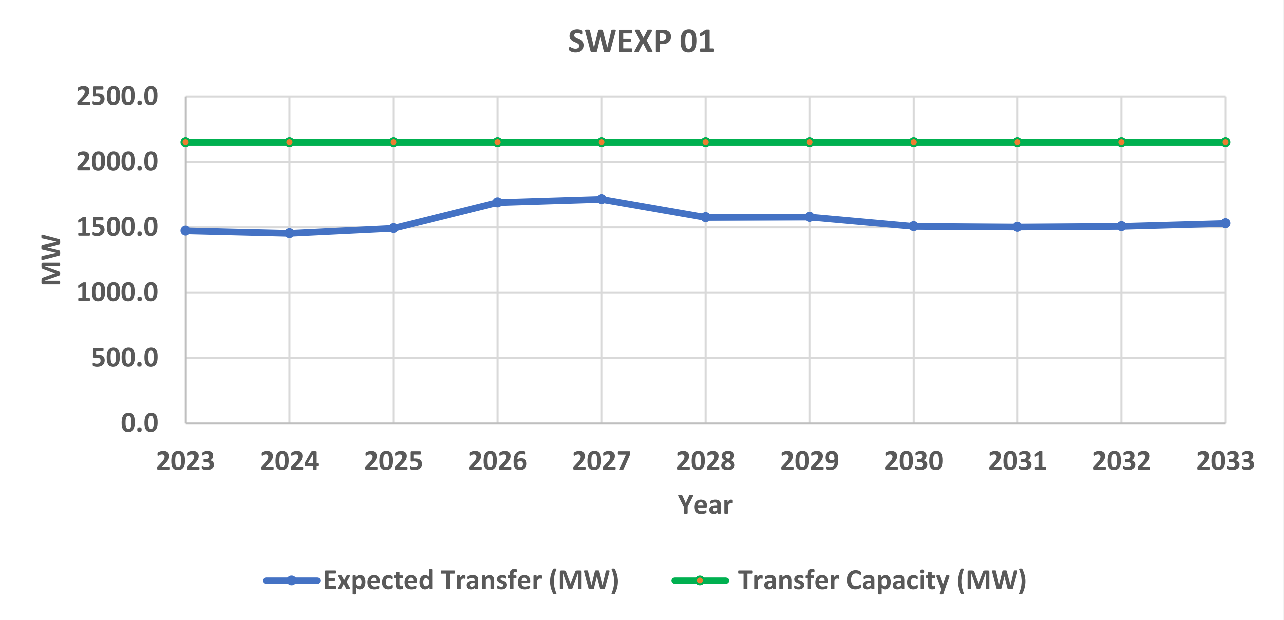

Figure 33: Expected transfer and transfer capacity in SWEXP 01 boundary – peak demand

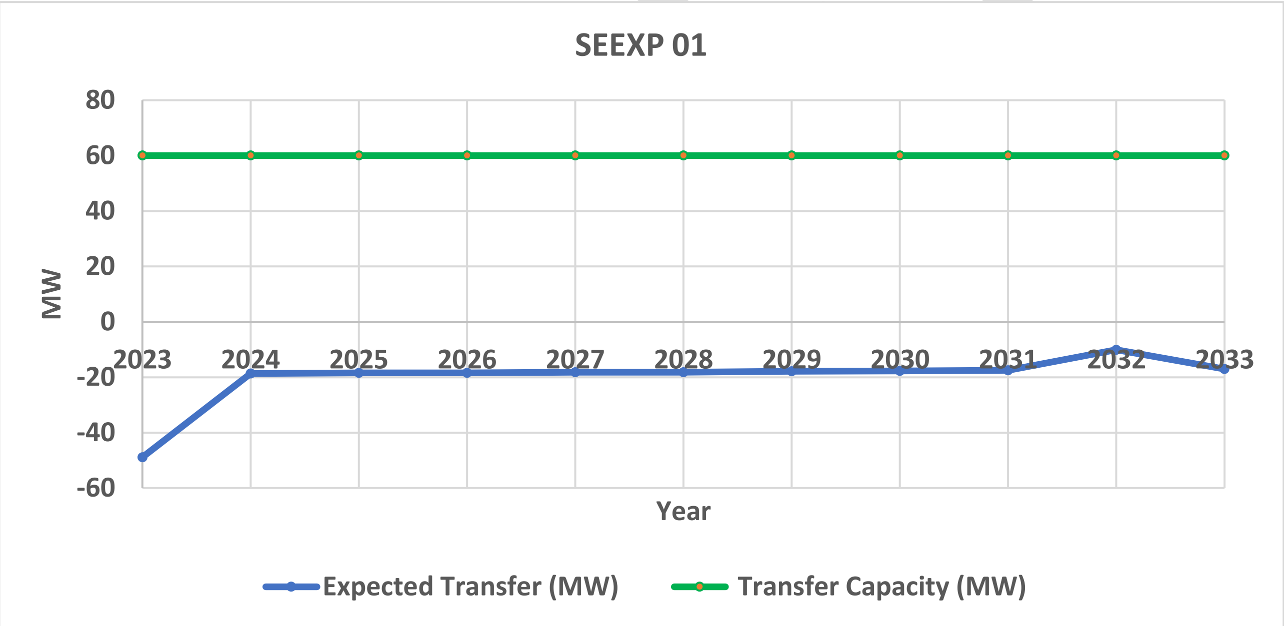

Figure 34: Expected transfer and export transfer capacity in SEEXP 01 boundary – peak demand

Over the study period, available export capacity within the SWEXP 01 boundary increases due to the planned retirement of the Muja G5 and G6 units by 2024, Collie Power Station by 2027 and Muja D units by 2029, this is offset by proposed BESS projects connecting across the study period. The expected transfers for the SEEXP 01 boundary remain a net importer of power during high generation and peak demand conditions, presenting opportunities for new generation connections at 132 kV.

11.3.2 Thermal Constraints - Transmission Lines

A number of post contingent thermal overloads arise within the South Region during peak conditions and under certain dispatch scenarios. For example:

- Pinjarra to Alcoa Pinjarra 132 kV line overloads occur by 22/23 and increases up to 110 per cent, following the loss of the four-ended Picton to Busselton 132 kV circuit

- Capel to Busselton No.1 66 kV line overloads occur by 29/30 and increases up to 128 per cent, following the loss of the four-ended Picton to Busselton 132 kV circuit
- Capel to Busselton No.2 66 kV line overloads occur by 30/31 and increases up to 111 per cent, following the loss of the four-ended Picton to Busselton 132 kV circuit
- Picton to Capel/Westralian Sands 66 kV line overloads occur by 28/29 and increases up to 126 per cent, following the loss of the four-ended Picton to Busselton 132 kV circuit
- Picton to Capel No.2 66 kV line overloads occur by 31/32 and increases up to 103 per cent, following the loss of the four-ended Picton to Busselton 132 kV circuit
- Kojonup to Wagin 66 kV line overloads occur by 22/23 at 112 per cent and drops to 101 per cent by 32/33, following the loss of Kojonup to Katanning 66 kV line [33]

Western Power currently manages the thermal constraints through operational measures including special protection schemes[34].

11.3.3 Thermal Capacity – Transformers

Terminal Transformers

No post contingent thermal overloads arise within the South Region over the study period during peak conditions on the following bulk terminal transformers.

Zone Substation Transformers

This section shows the existing and forecast peak load utilisation across the period 2022/23 to 2032/33for all zone substations operated by Western Power within the South Region.

Table 11: Utilisation legend (for Table 12)

LEGEND	Classification Name	Utilisation %
	Under utilised	below 40%
	Medium utilisation	>40% & 75%
	Highly utilised	>75% & 95%
	Over utilised	above 95%

[33] Special protection schemes at Kojonup and Katanning are in place to manage this overhead line overload along with alternative operating arrangements depending on the generation dispatch.

[34] Details of Special Protection Schemes have been shared with AEMO for operation of the system.

Table 12: South Region Zone Substation utilisation heat map

	Capacity	Actual Utilisation (%)	Forecast Utilisation (%)																				Mitigation
Substation	Current MVA	2023	2024		2025		2026		2027		2028		2029		2030		2031		2032		2033		
			POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	
Albany	60	101	102	93	102	94	103	95	105	97	108	100	110	102	112	104	113	105	116	108	120	111	Proposed replacement of old transformers progressively with larger sizes
Beenup	14	57	57	46	57	47	58	47	58	47	58	48	59	48	59	48	59	48	59	48	60	49	
Boddington	10	48	49	43	49	43	49	43	49	43	49	43	50	44	50	44	50	44	50	44	51	45	
Busselton	71	94	96	76	97	77	98	78	100	81	103	83	106	86	108	88	110	90	112	92	115	95	New third transformer in execution phase
Bridgetown	29	120	115	113	114	111	115	112	115	112	119	117	123	121	123	121	123	120	125	123	131	129	A large mining load partially non-reference is scheduled to be migrated to 132kV connection.
Bunbury Harbour	62	110	110	102	111	102	112	103	113	105	115	107	117	109	119	111	121	113	123	115	126	118	Managed by distribution transfers. Additional transformer option to be investigated
Capel	43	56	56	51	56	51	56	51	56	51	56	52	57	52	57	52	58	53	58	53	59	54	Asset condition transformer replacements
Coolup	12	73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Coolup load transferred to Wagerup (2022) to facilitate substation decommissioning
Collie	30	57	58	54	58	54	58	54	58	54	59	55	59	55	60	55	60	56	60	56	61	57	
Katanning	20	80	80	77	79	76	79	75	80	76	81	77	82	77	82	78	82	77	82	78	84	80	
Kojonup	10	46	46	34	46	34	47	34	47	34	47	35	48	35	48	35	48	35	49	36	49	36	
Mount Barker	44	18	18	17	18	17	18	16	18	16	18	16	18	17	18	17	18	16	18	16	18	17	
Manjimup	29	61	61	53	59	51	57	49	57	49	58	50	58	50	58	50	57	49	56	48	57	48	

	Capacity	Actual Utilisation (%)	Forecast Utilisation (%)																				Mitigation
Substation	Current MVA	2023	2024		2025		2026		2027		2028		2029		2030		2031		2032		2033		
			POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	
Margaret River	37	60	60	48	61	48	61	49	61	49	63	50	63	51	64	52	65	53	66	54	67	55	
Marriot Road	67	69	71	66	72	67	73	68	73	68	73	68	73	68	74	69	75	70	76	70	76	71	
Narrogin	40	44	44	42	44	42	44	42	45	42	45	43	45	43	46	44	46	44	47	45	47	45	
Picton	74	58	58	56	58	56	58	56	58	56	59	57	59	57	60	58	60	58	61	59	61	60	
Wagin	6	98	98	90	99	91	100	91	100	92	101	92	102	93	102	94	103	95	104	96	105	97	Asset condition transformer replacements Utilisation to be reviewed in future years
Wagerup	30	56	61	56	64	59	65	60	65	60	65	61	66	62	68	64	71	66	72	68	73	69	

11.3.4 Steady State Voltages

A number of existing voltage-related performance constraints arise within the South Region during peak demand conditions over the study period, including:

- Low voltages (0.67pu) and excessive voltage step conditions (-10.5 per cent) by 2023/24 at the Busselton 66 kV, Busselton 132 kV and Margaret River 66 kV busbars, following the loss of the four-ended Picton to Busselton 132 kV line.
- Low voltages (0.86pu) by 2022/23 at the Capel 66 kV busbar, following the loss of the four-ended Picton to Busselton 132 kV line.
- Low voltages (between 0.7 pu to 0.9 pu) and excessive voltage step conditions (-22.4 per cent) by 2023/24 at the Katanning and Wagin 66 kV busbars, following the loss of the Kojonup to Katanning 66 kV line.

A number of voltage-related performance constraints arise within the South Region during minimum demand conditions over the study period, including:

- High voltages (1.13pu) by 2022/23 at the Busselton 132 kV busbars, following the loss of the four-ended Picton to Busselton 132 kV line.

In addition, the Busselton Zone Substation transformers are reaching their minimum transformer tap position during daytime minimum demand conditions, losing the ability to control pre- and post-contingent voltages within network performance limits on the downstream 22 kV distribution networks.

11.3.5 Fault Levels

There are no fault level-related performance constraints within the South Region over the study period.

11.3.6 Stability

Similar to the North and East Regions, growing levels of inverter-based generation in the region have triggered the need to conduct system strength studies for all existing facilities in the South Region. The N-0 study results observed that all facilities are expected to retain control loop stability.

Though existing N-0 studies have not revealed any system strength limitations, given the limited number of synchronous generators in parts of the network Western Power expects that system strength issues will materialise under certain contingency conditions. Solutions to these issues could include retuning of the control parameters of a facility, installation of stabilising equipment (e.g., BESS, STATCOM, synchronous condensers) or operational constraints.

Further work is ongoing to refine the EMT models and undertake system studies for contingency conditions in the South Region.

11.3.7 Reliability

There are no reliability-related performance constraints within the South Region over the study period.

11.3.8 Asset

Existing asset performance constraints have been identified in the South Region within the study period. A number of zone and terminal substation transformers in degraded condition require mitigation within the study period, including:

- Wagin – 66/22 kV 5 MVA – T1 & T3
- Katanning – 66/22 kV 6 MVA – T1, T2 & T3
- Kojonup – 132/66 KV 20 MVA – T2
- Boddington – 132/22 kV 13 MVA -T3
- Albany – 132/22 kV 27 MVA -T1 & T3
- Beenup – 132/22 kV 27 MVA - T3
- Marriot Road– 132/22 kV 27 MVA - T3
- Picton – 132/66/22 kV 100 MVA - T1 & T2
- Narrogin South– 220/66 kV 27 MVA - T1
- Kemerton– 132/132 kV 225 MVA Quad Booster – T1

11.4 Network Augmentation Works

Completed, committed, and proposed transmission projects in the South Region are shown in **Table 13**.

Table 13: Completed, committed, and proposed projects – South Region

Project	Scope	Benefits of project	Network driver/s	By when	Lifecycle Status
Kemerton Terminal: New transformer	A new 330/132 kV 490 MVA transformer is installed at Kemerton terminal Substation	Address the degraded condition of the Kemerton Quad Booster. A third terminal transformer will also address an existing post-contingent thermal constraint and enable the connection of new loads in the area.	Asset Condition/ Growth - Thermal	FY2023/24	Completed
Coolup Substation - Decommissioning	Decommissioning of the 66 kV Coolup Substation and supplies and load transfers to Wagerup	Address degraded asset condition of the 66 kV Coolup Substation and supply lines.	Growth - Thermal	FY2023/24	Execution
Picton Substation: Transformer Replacement	Replace the existing 66/22 kV 27 MVA T3 transformer with a 132/22 kV 33 MVA transformer	Address degraded asset condition and accommodate increasing demand.	Asset Condition	FY2022/23	Completed

Project	Scope	Benefits of project	Network driver/s	By when	Lifecycle Status
Wagerup Substation: Transformer Replacement	Replace existing T1 transformer with a new 132/22 kV 33MVA transformer	Address degraded asset condition	Asset Condition	FY2023/24	Completed
Wagin Substation: Transformer replacement	A staged replacement of both 66/22 kV transformers (T1 & T3).	Address degraded asset condition.	Asset Condition	FY2024/25	Execution
Wagerup special protection scheme	Opens 132kV circuit breaker following contingency to manage capacity shortfall in Wagerup area	Address capacity shortfall	Growth – Thermal	FY2023/24	Execution
Kemerton special protection scheme	Opens 132kV circuit breaker following contingency to manage capacity shortfall in Kemerton area	Address capacity shortfall	Growth – Thermal	FY2023/24	Execution
Katanning Substation: Transformer Replacement	Replacement of existing 3 x 66/22 kV transformers with a single larger reconfigurable 132-66/22 kV, 33 MVA transformer	Address degraded asset condition and accommodate increasing demand	Asset Condition	FY2025/26	Scoping
Busselton Substation: Transformer Replacement	Replace existing 66/22 kV transformers (T1 & T3) with a third 132/22 kV, 33MVA transformer	Address degraded asset condition and accommodate increasing demand. Mitigate overvoltage issues in the Busselton and Margaret River substations during minimum demand conditions.	Asset Condition /Growth - Thermal	FY2025/26	Planning
Busselton Substation: Install reactive support	Install 2 x 5 MVAr 22 kV reactors at Busselton Substation	Mitigate the risk of over-voltages in the Busselton 22 kV distribution network during minimum demand conditions.	Growth - Voltage	FY2025/26	Execution
CAG 99[35]:	Uprate 132 kV line circuits Kemerton to Marriot No.1 & No.2	Alleviate the network supply constraints to facilitate the conversion of an interim non-reference connection to a full reference service	Customer driven	FY2023/24	Execution

11.5 Network Opportunities

This section highlights possible network opportunities and network solutions in the South Region over the study period. These opportunities will be explored further during the scoping and planning phases of the

[35] Competing Applications Group

project lifecycle. If the opportunities are not a technically and economically viable, network solutions will be implemented to address the identified network constraints.

Table 14: Network Opportunities projects – South Region

Location	Scope/Issue	Market Opportunity	By when	Lifecycle Status	Proposed Network Solution
Albany	Asset Condition / Growth - Thermal	Address the degraded condition of the asset and accommodate increasing demand.	FY2026/27	Initiation	A staged replacement of both 132/22 kV, 33 MVA transformers (T1 & T3)
Bunbury	Growth – Thermal	Address existing substation capacity shortfall and accommodating increase demand in the area	FY2025/26	Initiation	Installation of a fourth 132/22 kV, 33 MVA transformer
Capel	Asset Condition / Growth - Thermal	Address the degraded condition of the asset and accommodate increasing demand	FY2026/27	Initiation	Replacement of existing 66/22 kV transformers (T1 & T3) with a single larger reconfigurable 132-66/22 kV, 33 MVA transformer.
Busselton Substation	Post-contingent over-voltages	Increase demand in the Busselton and Margaret River area during daytime minimum demand conditions to minimises the risk of post-contingent over-voltages.	FY2025/26	Planning	Installation of two new 5 MVAr 22 kV reactors at Busselton
Picton South Transmission Reinforcement – Stage 1 & 2	A staged 132 kV voltage conversion of the existing 66 kV supplies between Picton-Capel-Busselton.	Reduce the demand supplied in the Picton South area during peak demand conditions to potentially reduce or defer network augmentation to increase the power transfer capacity to the area.	FY2026/27	Initiation	A staged 132 kV voltage conversion of the existing 66 kV supplies between Picton-Capel-Busselton.
SW IMP 02 and SE IMP 01 import boundary	Spare available import capacity	An opportunity exists to utilise spare available capacity within SW IMP 02 and SE IMP 01 import boundaries by increasing demand of existing loads or via the connection of new loads	Across the study period	N/A	Spare available import capacity exists over a number of import boundaries within the South Region.

Location	Scope/Issue	Market Opportunity	By when	Lifecycle Status	Proposed Network Solution
SW EXP 01 and SE EXP 01 export boundary	Spare available export capacity	An opportunity exists to utilise spare available capacity within the SW EXP 01 and SE EXP 01 export boundaries by connecting new generation.	Across the study period	N/A	Spare available export capacity exists over a number of export boundaries within the South Region.

11.6 Emerging Issues and Drivers

Despite several existing constraints on the 132 kV networks, the 330 kV network in the region is expected to be increasingly under-utilised. There is sufficient capacity to support large new loads and generation connections at this voltage level.

The progressive retirement of coal-fired generation at Muja and Collie is expected to create challenges in the area, particularly as these units are critical in providing voltage control within and external to the region and contribute a significant portion of system inertia and strength which will be lost upon their retirement. Along with the recent announced plans, Western Power is expected to work with industry and AEMO to identify system and network constraints and develop prudent and timely network development options to facilitate these retirements.

Several 66 kV networks (i.e., Muja to Collie, Kojonup to Katanning to Narrogin) within the South Region will either be retired or upgraded to 132 kV as they approach their end of service life. Several long 132 kV circuits (i.e., Picton-Worsley 81 & Muja-Bunbury Harbour 81) are also approaching their end of service life within the next 10 to 20 years. Western Power is investigating several replacement options, including the potential to de-mesh parts of the South Region to simplify power flows within and out of the region.

12. East Region

12.1 Geography

The East Region covers the network east of (and including) Sawyers Valley, through to Kondinin, Kalgoorlie and the Goldfields. **Figure 35** shows the transmission system in the region.

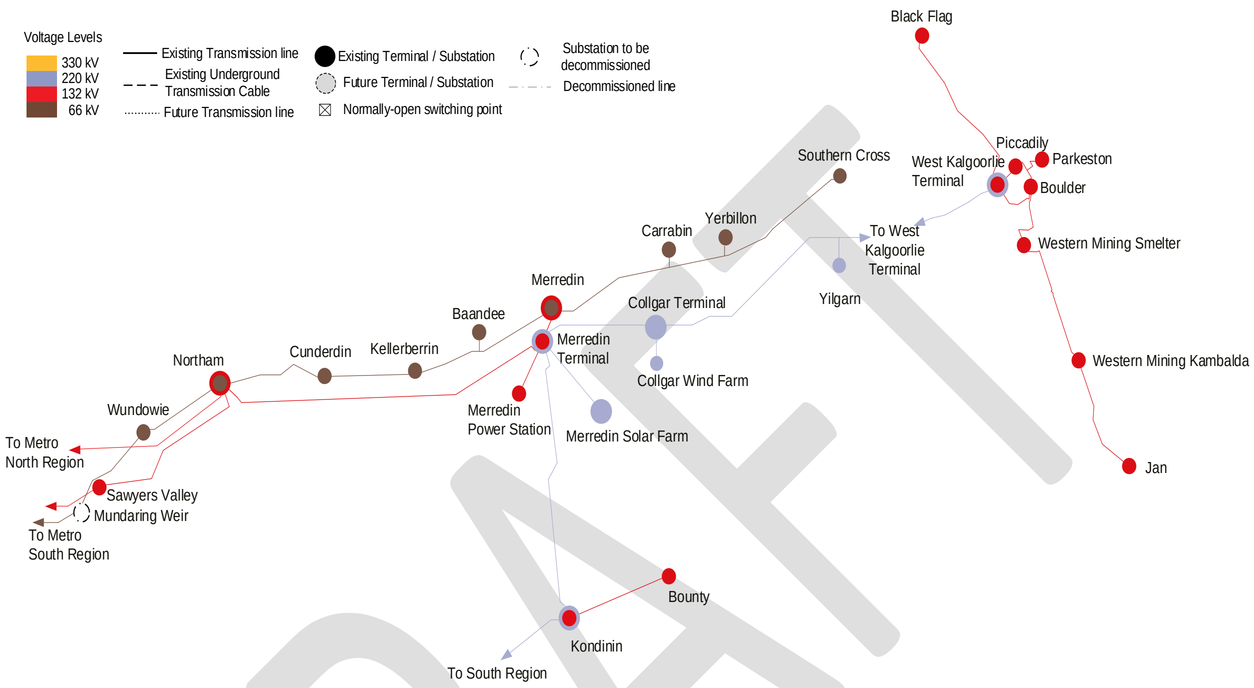

Figure 35: Western Power's East Region – Network Diagram

The East Region features six terminals and 19 zone substations that are owned and operated by Western Power. The other transmission sites in East Region are customer-owned substations.

Terminals:

- Collgar Terminal– 220 kV (Customer)
- Kondinin Terminal – 220 kV
- Merredin Terminal – 220/132/22 kV
- Northam Terminal – 132/66 kV
- West Kalgoorlie Terminal – 220/132 kV
- Yilgarn Terminal – 220/33/22 kV

Zone Substations / WP Substations

- Bandee – 66 kV
- Black Flag – 132/33 kV
- Boulder – 132/33 kV
- Bounty – 132/33 kV
- Carrabin – 66/22 kV
- Cunderdin – 132/33 kV
- Kellerberrin – 66/22 kV
- Kondinin – 220/33 kV
- Mundaring Weir – 66/6.6 kV
- Merredin – 132/22 kV
- Mundaring Weir – 66 kV[36]
- Northam – 66/22 kV

[36] MW load transferred to SVY, 66kV energised

- Piccadilly – 132/11 kV
- Sawyers Valley – 132/22 kV
- Southern Cross – 66/33 kV
- West Kalgoorlie – 132/11 kV
- West Kalgoorlie – 132/33 kV
- Wundowie – 66/22 kV
- Yerbillon – 66/0.44 kV
- Yilgarn – 220/33 kV

Customer substations

- Collgar Wind Farm – 220 kV
- Edna May Operations – 66 kV
- Jan – 132 kV
- Merredin Power Station – 132 kV
- Parkeston – 132 kV
- Western Mining Kambalda – 132 kV
- Western Mining Smelter – 132 kV

12.2 Regional Characteristics

12.2.1 General

There is a combination of residential and mining loads in the East Region. Substations from Sawyers Valley through to Kalgoorlie are a mixture of low density residential and agricultural loads. The customers south of Southern Cross (to the east) through to the Goldfields are predominately high-density mining, industrial and agricultural load.

The demand in this region is heavily sensitive to commodity prices. This makes planning difficult, with new connections typically being block loads to connect new mining loads, which makes them difficult to forecast due to their inherent volatility in response to market economics. Considerable uncertainty in demand forecasts in turn creates difficulties when evaluating the need to commit to transmission system augmentation. Industrial load decarbonisation is increasing the level of connection enquiries in this region.

12.2.2 Generation

There is more than 750 MW of generation throughout the East Region, including a significant amount of gas-fired generation installed in the Goldfields that is owned and operated by independent power producers servicing the mining sector. There is also a mixture of solar and wind generation within the region and during some operating conditions where renewable generation output is high, it can be a net exporter of power. Traditionally the EC load has not had local generation, however with the entrants' generations such as Collgar Wind Farm and Merredin Power Station, the Region became a net generation exporter under some conditions.

12.2.3 Existing Transmission Network Supply

The East Region is predominantly supplied via the 220 kV line from Muja and the 132 kV networks connected to the Metro North Region, via the Northern and Guildford terminals. A large sub-transmission 66 kV network also extends from Cannington Terminal (in the Metro South Region) through to Southern Cross Substation towards the Goldfields.

The 220 kV line from Muja to West Kalgoorlie Terminal (via Kondinin and Merredin Terminal) is more than 650 km long. This circuit provides supply to Kalgoorlie and the Goldfields and is designed to an N-0 security standard. Under system normal conditions, the 66 kV line between Cunderdin and Kellerberrin is out of service to maintain system security.

Due to the relatively low capital cost of installing protection and control schemes compared to transmission overhead line reinforcement options in Kalgoorlie and the Goldfields, many protection and control schemes have been installed in recent years. The purpose of these schemes includes providing new customers with non-reference services through runback schemes and fast tripping protection schemes that island customers or isolate parts of the network.

12.2.4 Key Developments in the Region

New load connections in the region have historically been challenging due to network limitations that arise on 220 kV supply when assessing connections under unconstrained basis. Western Power has recently adopted a more flexible approach when assessing customers and has offered non-reference solutions to customers looking to connect to the network.

Due to the demand for non-reference services in the region, Western Power has developed the Eastern Goldfields Load Permissive Scheme (ELPS). This scheme is used to signal capacity in operational real-time to several non-reference customers. Should the 220 kV line reach critical pre-contingent levels, non-reference customer loads are curtailed to maintain system security.

Due to aging Static VAR compensators in the East Region, Western Power has upgraded the SVCs with more modern STATCOM technology across several sites within the Goldfields area, including Boulder, Piccadilly and Western Kalgoorlie. These STATCOM devices provide fast-acting reactive power control to the region and together with a third 220/132 kV 250 MVA transformer at West Kalgoorlie Terminal, increased the power transfer capacity in the area to accommodate increases in demand in the area.

To further support the connection of both load and generation customers at part of the transition to net zero emissions there are further network investment proposed in the Eastern Region to increase capacity, see section 3.5.4. This proposed network augmentation will include a series of staged investment in the East Country and Eastern Goldfields 220kV network to facilitate increased levels of new customer connections.

12.3 Network Performance

This section presents the network performance for the East Region over the study period.

12.3.1 Thermal Capacity – Boundaries

The following assumptions were made in developing the import and export boundaries:

- Import boundaries consider peak demand and security constrained and economic dispatch conditions
- Export boundaries consider peak demand and maximum generation dispatch conditions (within boundary)

Import Boundaries

Figure 36 shows the most active network import boundaries in the East Region. These boundaries are defined using the worst contingency (↯) and the worst overload circuit (*) as given in **Table 15**.

The expected transfer and transfer capacity for each of the import boundaries across the study period are shown in **Figure 37** to **Figure 39**.

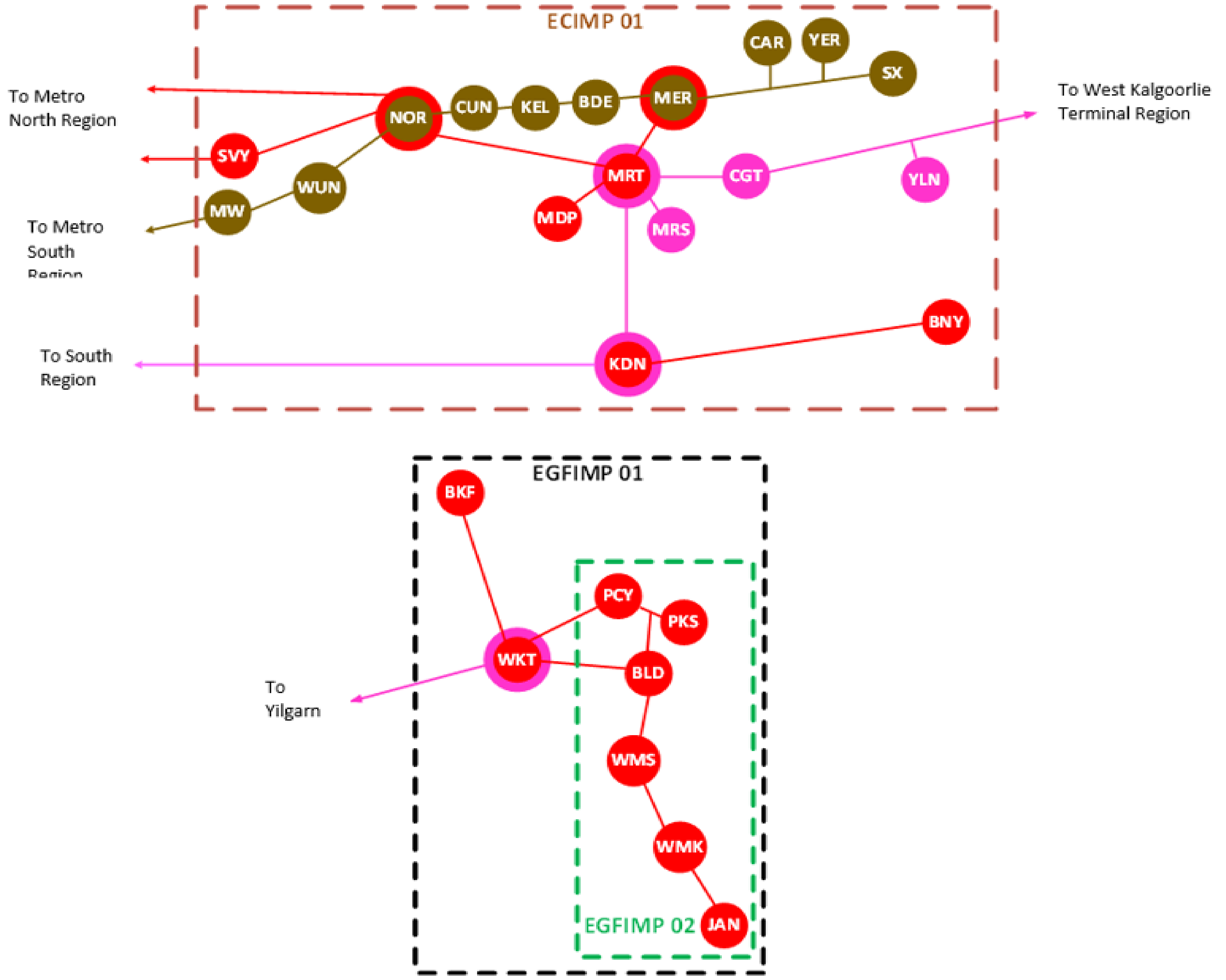

Figure 36: Network import boundaries in the East Region

Table 15: Thermal import boundaries characteristics – East Region

Characteristics	Import Boundaries		
	ECIMP 01	EGFIMP 01	EGFIMP 02
Worst contingency	Darlington-Sawyers Valley 81	West Kalgoorlie Tx	West Kalgoorlie-Piccadilly 81
Contingency type	N-1	N-1	N-1
Worst circuit/s	Northern Terminal-Northam 81	West Kalgoorlie Tx	West Kalgoorlie – Boulder 81

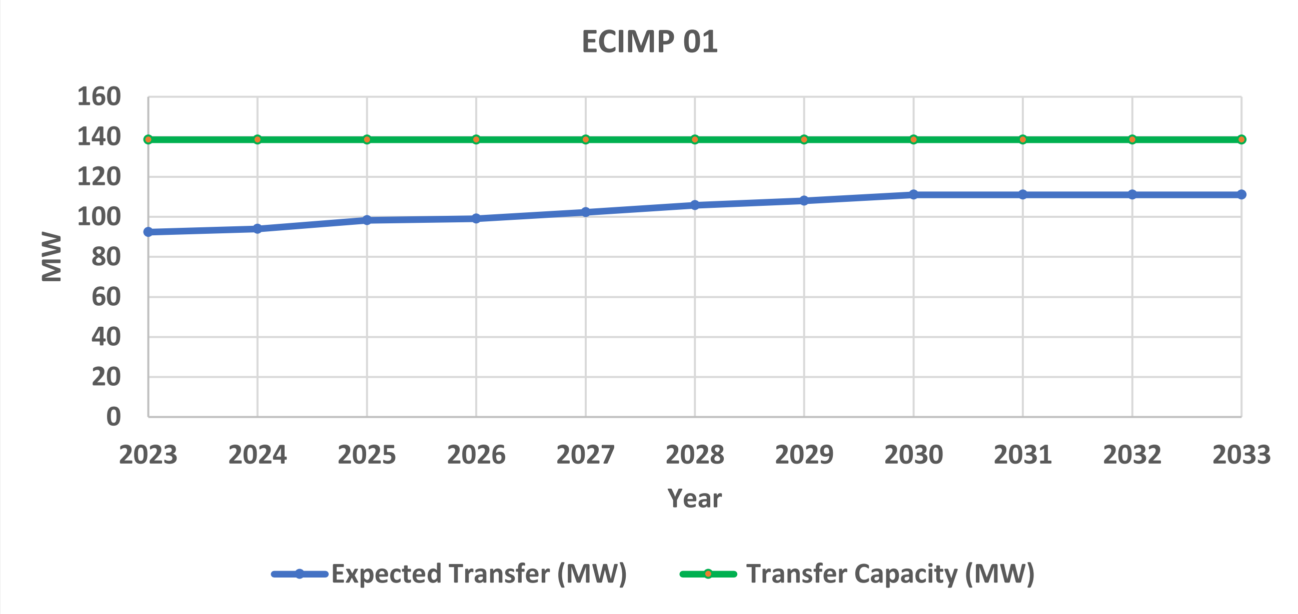

Figure 37: Expected transfer and transfer capacity in ECIMP 01 boundary – peak demand

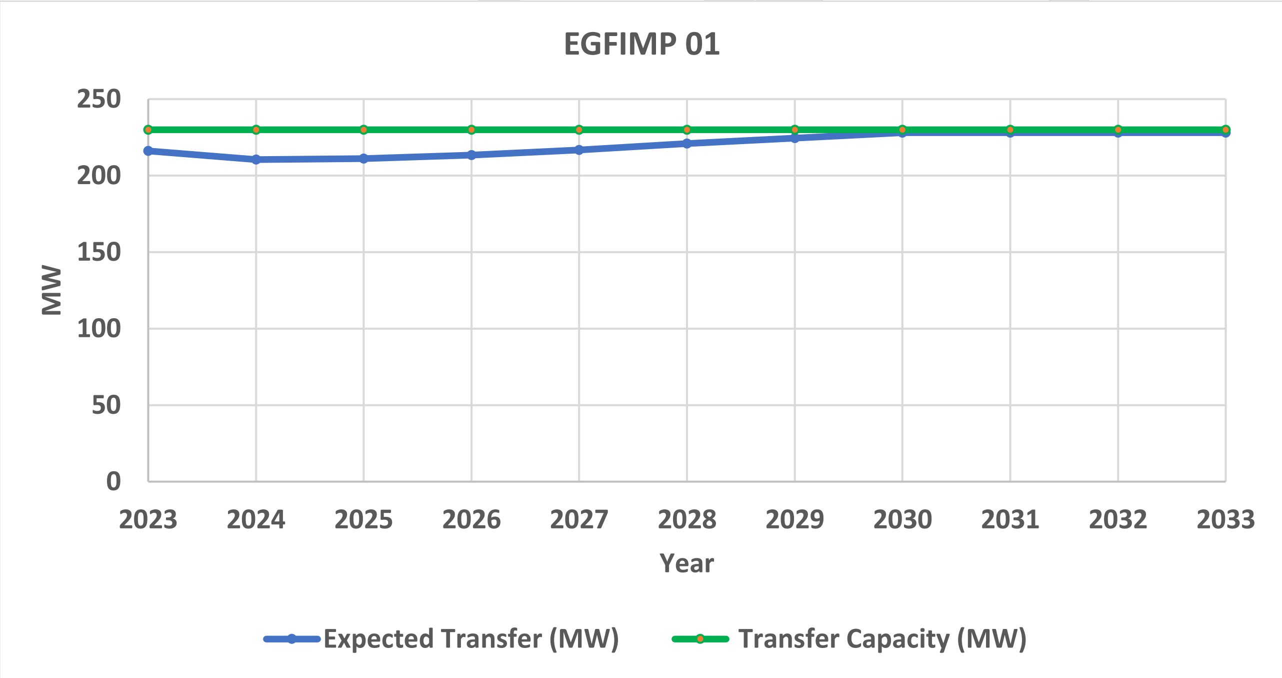

Figure 38: Expected transfer and transfer capacity in EGFIMP 01 boundary – peak demand

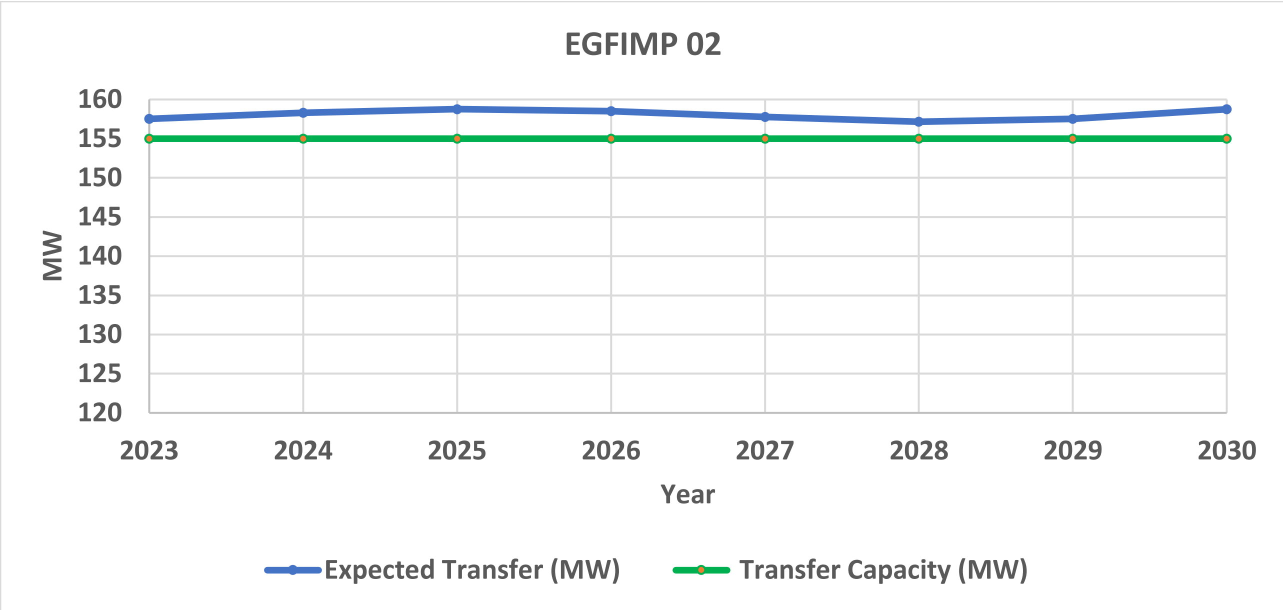

Figure 39: Expected transfer and transfer capacity in EGFIMP 02 boundary – peak demand

Figure 37 shows that the ECIMP 01 has enough capacity to accommodate between approximately 60 MW and 30 MW over the ten-year study period.

Figure 38 and **Figure 39** show that the expected transfer into Eastern Goldfield (both EGFIMP 01 and EGFIMP 02) import boundaries is above or close to the transfer capacity during the 10-year study period. So, the limitations in the EGF area (EGFIMP 01 and EGFIMP 02) impact the capability of connecting new loads, however the ELPS scheme in the area to manage these potential overload risks. In addition, the majority of the non-reference loads are supplied from the Boulder and West Kalgoorlie substations.

Export Boundaries

Figure 40 shows the most active network import boundaries in the East Region. These boundaries are defined using the worst contingency (⚡) and the worst overload circuit (*) as given in **Table 16**.

The expected transfer and transfer capacity for each of the export boundaries across the study period are shown in **Figure 41** and **Figure 42**.

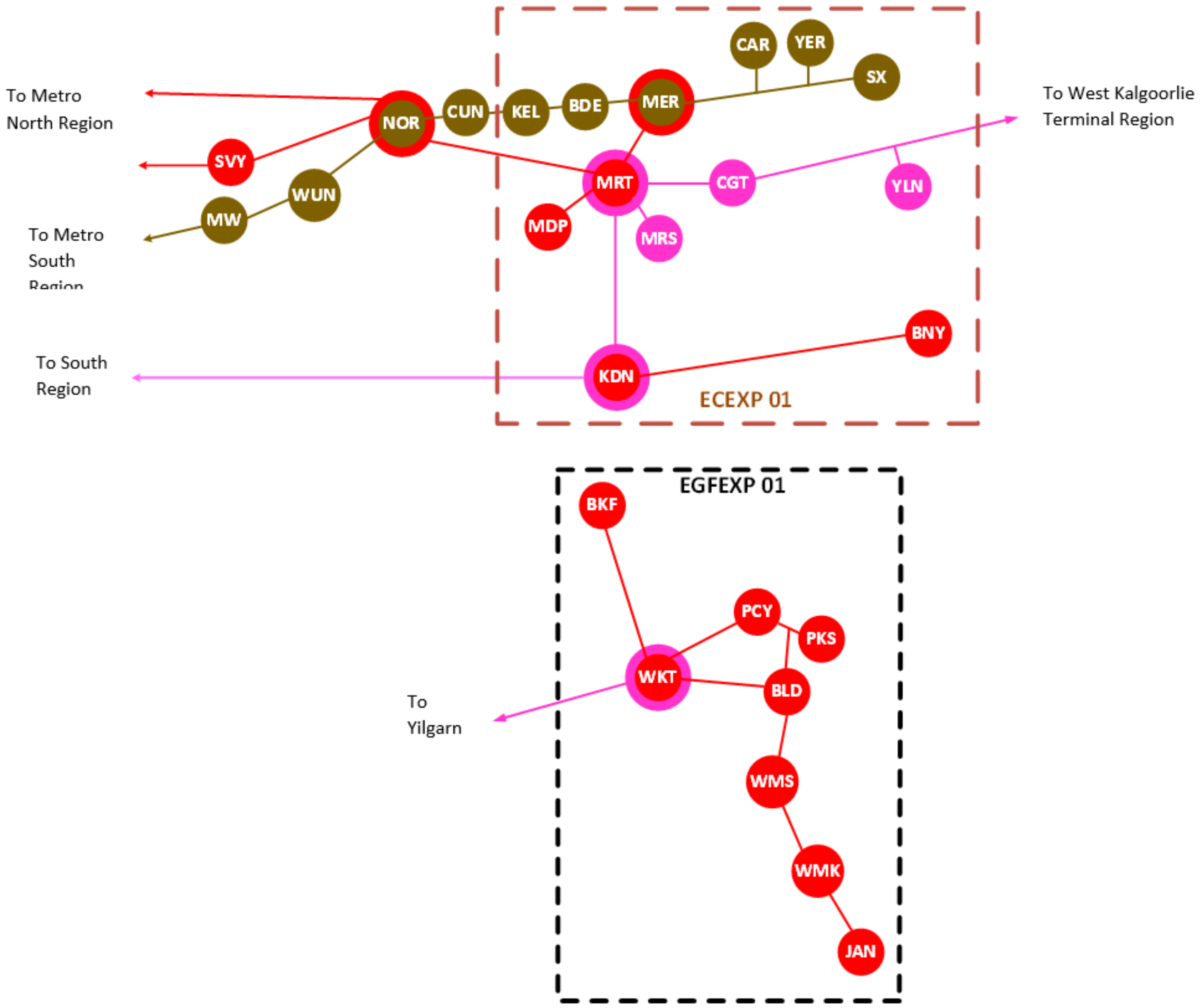

Figure 40: Network import boundaries in the East Region

Table 16: Thermal export boundaries characteristics – East Region

Characteristics	Export Boundaries	
	ECEXP 01	**EGFEXP 01**
Worst contingency	N/A	West Kalgoorlie Tx
Contingency type	N-0	N-1
Worst circuit/s	Merredin Terminal – Northam 81	West Kalgoorlie Tx

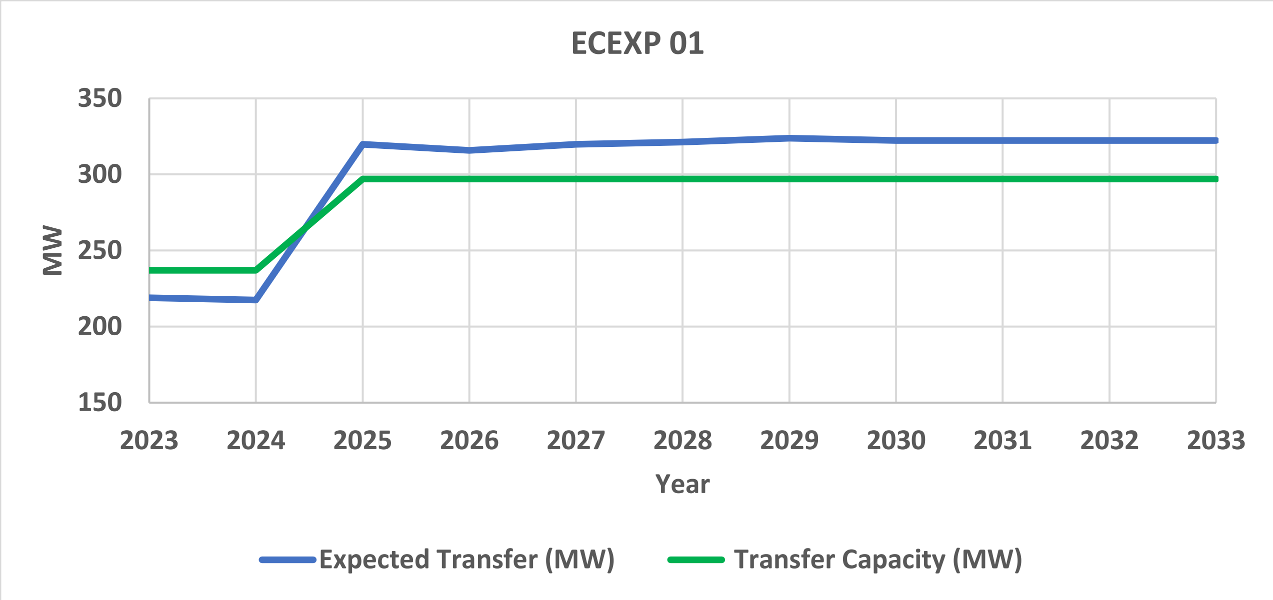

Figure 41: Expected transfer and transfer capacity in ECEXP 01 boundary – peak demand

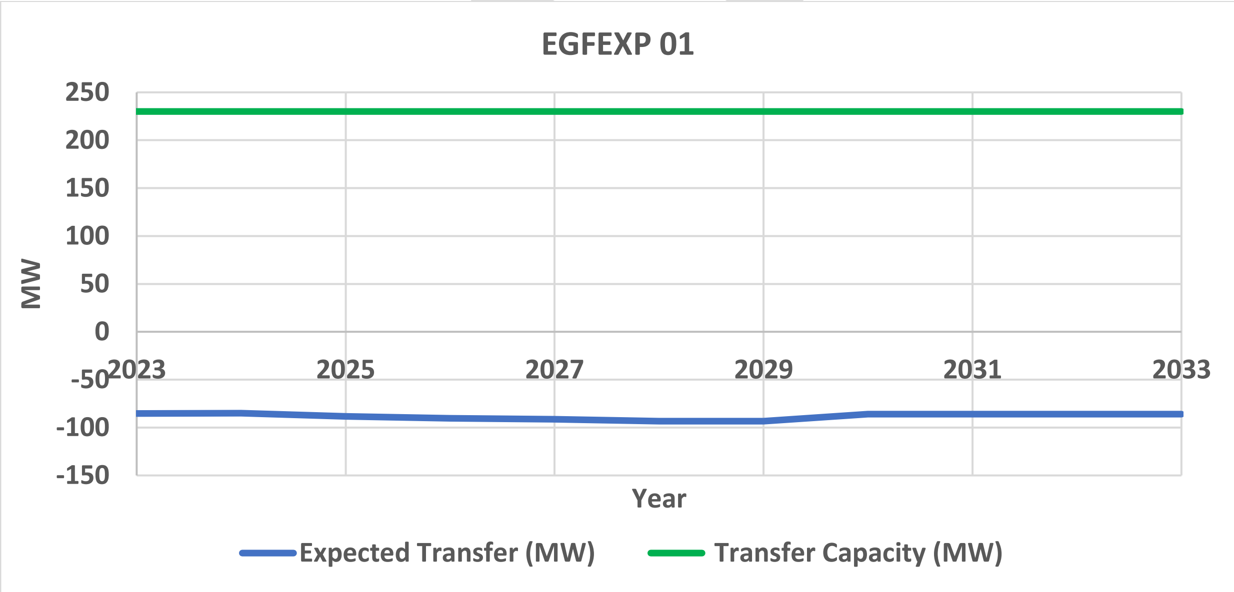

Figure 42: Expected transfer and transfer capacity in EGFEXP 01 boundary – peak demand

The EC EXP 01 export boundary is limited pre-contingently because of high renewable generation output in the area. An existing post-contingent runback scheme manages transfer levels across the Northern Terminal to Merredin 132 kV circuit by curtailing the output of the Collgar wind farm. Additional generation in the region that contributes to this constraint will also require a similar runback scheme.

Although the EGF EXP 01 export boundaries have sufficient available thermal export capacity throughout the study period, it is important to note that stability constraints in this boundary are likely to bind before thermal constraints, reducing the available capacity shown in **Figure 42**. Western Power is working to develop simplified ways to represent stability constraints that can arise due to multiple factors, making it more difficult to represent than thermal constraints.

12.3.2 Thermal Capacity – Transmission Lines

Post contingent thermal overloads arise during peak demand conditions within the East Region over the study period on the following circuits

- MRT-NOR 132 kV line overloads occur by 2022/23 and increase up to 155 per cent, following the loss of the KDN-MRTX1 132 kV line.
- NOR-MRT/CNS81 Road 132 kV line overloads occur by 2031/32 and increase up to 107 per cent, following the loss of the WKT-BKF 132 kV line.

  There are some mitigation schemes for thermal limits and voltage stability limitations in the EGF load area including, some special control schemes, Eastern Goldfields NCESS contract, ELPS, BKF Inter-trip scheme and EREP (refer section 3.5.4).

12.3.3 Thermal Capacity – Transformers

This section shows the existing and forecast peak load utilisation across the period 2022/23 to 2032/33 for all zone substations operated by Western Power within the East Region.

Table 17: Utilisation legend (for Table 18)

LEGEND	Classification Name	Utilisation %
(green)	Under utilised	below 40%
(light green)	Medium utilisation	>40% & 75%
(orange)	Highly utilised	>75% & 95%
(red)	Over utilised	above 95%

Table 18: East Region Zone Substation utilisation heat map[37]

	Capacity	Actual Utilisation (%)	Forecast Utilisation (%)																						Mitigation
Substation	MVA	2023	2023		2024		2025		2026		2027		2028		2029		2030		2031		2032		2033		
			POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	
Black Flag[38]	31	138	138	131	137	129	136	128	137	129	139	132	143	135	146	139	149	142	151	143	153	145	154	147	Additional 33 MVA transformer (FY2026/27)
Boulder	62	68	68	52	69	54	72	56	73	57	73	57	73	57	74	58	76	61	79	63	80	64	80	64	
Bounty	10	203	203	199	210	205	211	206	212	208	214	209	216	211	217	213	219	214	221	216	222	218	224	220	TR exemption in place. Capacity increase to 27 MVA
Carrabin	6	14	14	13	14	13	14	13	14	13	14	13	14	13	14	13	14	13	14	13	14	13	15	13	
Cunderdin	14	70	70	64	70	64	70	64	71	64	71	65	71	65	72	65	72	66	72	66	73	66	73	67	
Kondinin	29	41	41	35	41	35	41	35	41	35	41	36	41	36	42	36	42	36	42	36	42	37	43	37	
Kellerberrin	6	56	56	47	55	47	55	47	55	46	54	46	54	45	54	45	53	45	53	44	53	44	53	44	
Merredin	13	89	89	78	89	78	88	78	88	77	88	78	89	78	89	79	89	79	89	79	89	79	90	80	
Northam	41	75	75	71	76	73	88	84	89	86	91	87	93	89	95	91	97	93	99	96	102	98	105	101	Asset condition transformer replacements
Piccadilly	64	56	56	49	55	49	55	49	54	49	54	48	54	48	54	49	54	49	55	50	55	50	56	51	
Sawyers Valley	56	46	46	38	46	39	66	58	66	58	66	58	66	59	67	59	67	59	67	60	68	60	68	61	
Southern Cross	13	46	46	24	47	25	47	25	47	25	47	25	48	25	48	26	48	26	49	26	49	27	49	27	
West Kalgoorlie 11 kV	31	77	77	42	77	42	75	40	74	39	74	39	75	40	76	41	76	41	76	41%	76	41	77	42	
West Kalgoorlie 33 kV[38]	30	117	117	94	122	99	124	100	124	101	124	101	124	101	125	102	127	103	128	105	129	106	129	106	New distribution block load in 2022. Additional 33 MVA transformer (FY2026/27)
Wundowie	16	71	71	66	71	67	71	67	1	1	1	1	1	1	2	2	2	2	3	3	3	3	4	4	Asset condition transformer replacements and noise compliance
Yerbillon	4	101	101	68	103	70	104	71	104	71	104	71	104	71	105	72	106	74	107	76	109	77	110	79	
Yilgarn	29	45	45	41	45	41	44	41	44	40	43	41	43	41	43	41	43	41	44	41	44	41	44	42	

37 Baandee substation uses estimated data due to insufficient real-time demand measurements, which have been reviewed as inaccurate. As a result, they have been removed.

38 A portion of non-reference customers have curtailable load such that the substation does not exceed capacity.

12.3.4 Steady State Voltages

There are no voltage-related performance constraints within the East Region over the study period.

12.3.5 Fault Levels

There are no fault rating-related performance constraints within the East Region over the study period.

12.3.6 Stability

The long length and relatively high impedance of the 220 kV Muja to West Kalgoorlie, presents operational challenges in terms of system stability. Transient limitations are by the relatively low inertia of generating units and the transient voltage instability limits that arise due to insufficient reactive reserve. Special protection schemes and NCESS are in place to manage these limitations.

Oscillatory stability issues (small signal) have also been identified between machines in the area and other SWIS generating units. The capacitive and inductive impedance configuration of the 220 kV system can, under certain conditions, give rise to sub-harmonic oscillations. Western Power installed a dynamic power system-monitoring tool (Psymetrix) that enables better identification of oscillatory stability related issues in the area to improve network security.

Similar to the North and South Regions, growing levels of inverter-based generation in the East Region have triggered the need to conduct system strength studies for all existing facilities. The N-0 study results observed that all facilities are expected to retain control loop stability.

Though the existing N-0 studies have not revealed any system strength limitations, given the limited number of synchronous generators in parts of the network Western Power expects that system strength issues will materialise under certain contingency conditions. Solutions to these issues could include retuning of the control parameters of a facility, installation of stabilising equipment (e.g., BESS, STATCOM, synchronous condensers) or operational constraints.

Further work is ongoing to refine the EMT models and to undertake system studies for contingency conditions in the East Region.

12.3.7 Reliability

Due to a single connection to the rest of the network via a 220 kV circuit, supplies to Kalgoorlie and the Goldfields are operated to a N-0 supply standard, presenting a reduced level of security. Provisions in the Technical Rules envisage supply to Boulder, Kalgoorlie and Coolgardie town load to have N-1 reliability. In 2018, amendments to the NQRS Code were made to enable reliability of supply during planned outages of the network equipment. This reliability is currently provided under an NCESS arrangement, with historical and future performance shown in **Figure 43**.

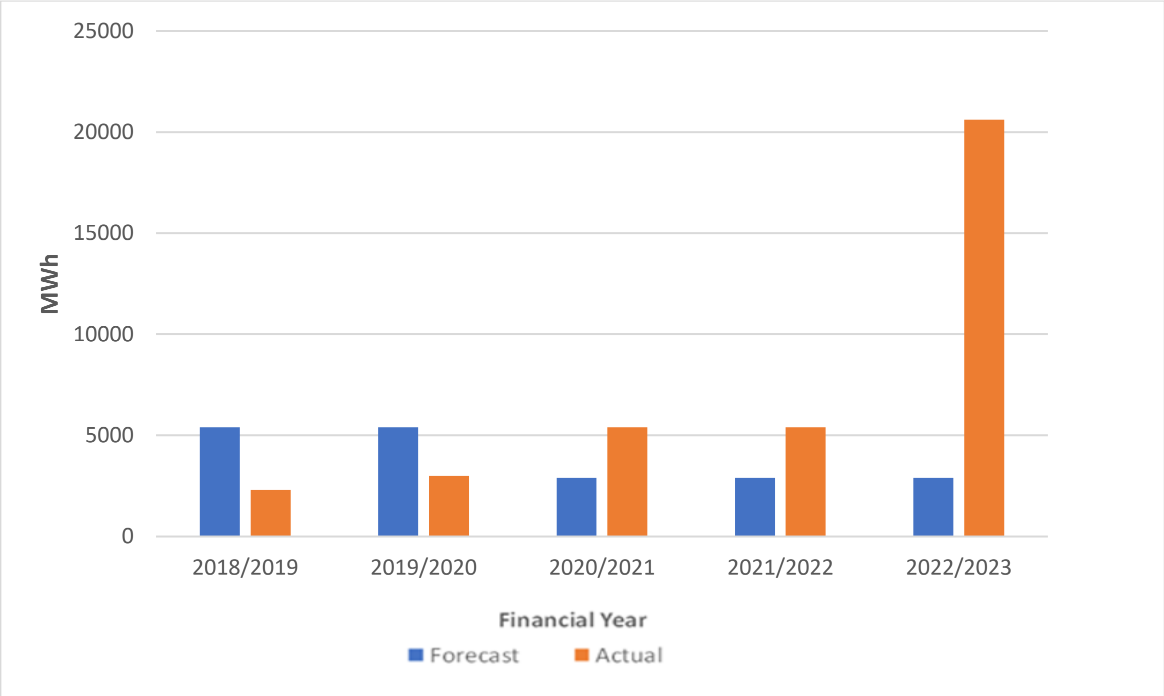

Figure 43: NCESS operation in the East Region

12.3.8 Asset

Existing asset performance constraints were identified in the East Region within the study period, including:

- A number of zone and terminal substation transformers in degraded condition require mitigation within the study period, including:
    - Northam – 66/22 kV 15 MVA – T1, T2 and T3
    - Southern Cross – 66/33 kV 12 MVA – T1 and T2
    - Merredin – 66/22 kV 13 MVA – T2
    - Cunderdin – 66/22 kV 15MVA – T2
    - Northam – 132/66 kV 37.5 MVA – T1 and T2
    - Kondinin – 220/33 kV 27 MVA Auto-Transformer T1
    - Black Flag – 132/33 kV 27 MVA – T2 and T3
    - Boulder – 132/33 kV 27 MVA – T1, T2 and T3
    - Bounty – 132/33 kV 27 MVA – T1
    - West Kalgoorlie – 132/33 kV 27 MVA – T5
    - Yilgarn – 220/33 kV 27 MVA – T2
- The 11 kV switchboards at Piccadilly are in degraded condition and need to be addressed in the next 10 years.

12.4 Network Augmentation Works

Completed, committed, and proposed transmission projects in the East Region are shown in **Table 19**.

Table 19: Completed, committed, and proposed projects – East Region

Project	Scope	Benefits of project	Network driver/s	By when	Lifecycle Status
Northam Substation: Transformer Upgrade	Remove the existing 3 x 66 kV transformers and install one 132/22 kV,33 MVA unit	Address degraded asset condition	Asset Condition	FY2023/24	Execution
Cunderdin Substation: Solar Farm generation connection	Installation of a new tee-off 132 kV substation on the Northam-Merredin terminal 81 circuit	Facilitate the connection of a new 100 MW solar farm.	Customer Driven	FY2023/24	Planning
Wundowie Substation: Decommissioning	Replace two existing transformers with two new 132-66/22kV,33MVA transformers.	Address degraded asset condition and noise compliance	Asset condition	FY2026/27	Planning
Mundaring Weir Substation: Decommissioning	The 66 kV Mundaring Weir Zone Substation is already de-energised[36]. This works involves decommissioning and removing the degraded 66kV substation assets.	Decommission and remove the degraded and redundant 66 kV substation assets	Asset condition	FY2028/29	Planning
Black Flag Substation: New Transformer	Installation of a new 132/33 kV, 33MVA transformer at Black Flag Substation.	Increase the Black Flag Substation capacity to accommodate increased demand in the area. Existing customers with a non-reference service may have the opportunity to convert a reference service.	Growth – Thermal	FY2026/27	Scoping
West Kalgoorlie Substation: New Transformer	Installation of a new 132/33 kV,33MVA transformer at West Kalgoorlie substation	Increase the WKT capacity to accommodate increased demand in the area. Existing customers with a non-reference service may have the opportunity to convert a reference service.	Growth – Thermal	FY2026/27	Scoping

12.5 Network Opportunities

This section highlights possible network opportunities and network solutions in the South Region over the study period. These opportunities will be explored further during the scoping and planning phases of the project lifecycle. If the opportunities are not a technically and economically viable, network solutions will be implemented to address the identified network constraints.

Table 20: Network Opportunities projects – East Region

Location	Scope / Issue	Market Opportunity	By when	Lifecycle Status	Proposed Network Solution)
Eastern Goldfields Load Permissive Scheme	The ELPS scheme is currently operational and provides a non-reference supply connection for a number of new loads into the Goldfields.	The ELPS can connect additional customers in the Goldfields under a non-reference arrangement.	Across the study period	N/A	N/A
EC IMP 01 available import capacity	Spare available import capacity exists over a number of import boundaries within the East Region.	An opportunity exists to utilise spare available capacity within EC IMP 01 import boundaries by increasing demand of existing loads or via the connection of new loads	Across the study period	N/A	N/A

12.6 Emerging Issues and Drivers

The long transmission supply lines throughout the East Region present significant challenges in alleviating network constraints due to high capital costs required to perform network upgrades. Additionally, most of the 66 kV assets between the Wundowie and Southern Cross substations are anticipated to be progressively retired or upgraded to 132 kV as they reach their end of service life.

In the short to medium term, it is anticipated that the ELPS will provide prospective load customers opportunity to connect under a non-reference service, resulting in higher utilisation of the 220 kV supply.

An upcoming challenge faced by the entire network is the retirement of coal-fired generation at the Muja and Collie power stations. This will have a large impact on the East Region, as the bulk of the region's power transfer comes from Muja via the single 220 kV circuit.

Over the medium to longer term, the transition away from fossil fuel generation is expected to significantly increase demand, particularly within the Goldfields area. Furthermore, the mining industry is anticipated to decarbonise faster than other industries, which is likely to increase demand on the already constrained 220 kV single circuit supply. Western Power is currently investigating several network augmentations options to support future demand scenarios, ranging from solutions that provide incremental increases in power transfer to large-scale network augmentation that will support higher decarbonisation demand scenarios. Depending on the amount of decarbonisation, an additional circuit may be required from Muja to the Goldfields.

Despite the presence of considerable renewable energy applications in the East Region's load area, the current transmission network in the area is insufficient and already operating at full capacity. As a result, Western Power is currently investing in several network augmentation and reinforcement operations to accommodate new generations of energy in this region.

Following the completion of the proposed East Region Energy Program Stage 1 works the network import capacity transfer from Metro North Region to East Country would increase by circa 25% whilst the export capacity transfer from East Country to Metro North & to South Region would increase by circa 50% and 20%, respectively.

13. Metro North Region

13.1 Geography

The Metro North Region covers the northern extent of the Perth metropolitan area and is bound by coastal and western suburbs in the west, Malaga and North Beach in the north, and the eastern suburbs and foothills areas of Forrestfield and Darlington in the east. **Figure 44** shows the transmission system in this region.

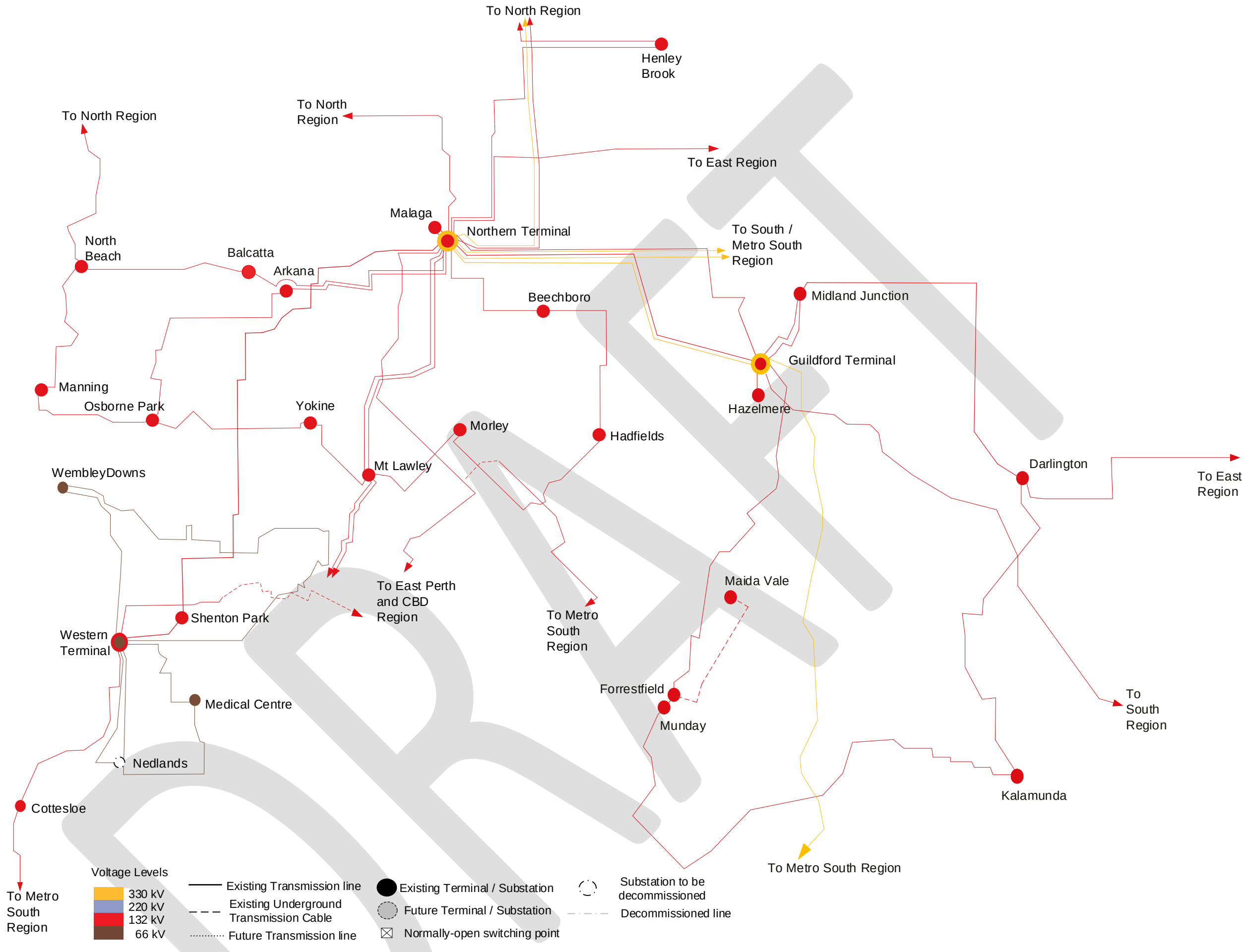

Figure 44: Western Power's Metro North Region – Network Diagram

The Metro North Region features three terminals and 23 zone substations that are owned and operated by Western Power. The other transmission sites in this region are customer owned substations.

Terminals:

- Guilford Terminal – 330/132 kV
- Northern Terminal – 330/132 kV
- Western Terminal – 132/66 kV

Zone Substations / WP Substations

- Arkana – 132/22 kV
- Beechboro – 132/22 kV
- Cottesloe – 132/11 kV
- Darlington – 132/22 kV
- Forrestfield – 132/22 kV
- Hadfield – 132/22 kV
- Hazelmere – 132/22 kV
- Henley Brook – 132/22 kV
- Kalamunda – 132/22 kV
- Malaga – 132/22 kV
- Manning Street – 132/11 kV
- Medical Centre – 66/11 kV
- Midland Junction – 132/22 kV
- Morley – 132/11 kV
- Mount Lawley – 132 kV (switchyard)
- Munday – 132/22 kV
- Nedlands – 66/6.6 kV
- North Beach – 132/22 kV
- Osborne Park – 132/11 kV
- Shenton Park – 132/11 kV
- Wembley Downs – 66/11 kV
- Yokine – 132/11 kV

Customer Substations

- Maida Vale – 132/25 kV
- Whiteman Park – 132 kV

13.2 Regional Characteristics

13.2.1 General

The Metro North Region has a variety of loads. The area around the Western Terminal is predominantly residential, with some commercial and light industrial loads. Heavy industrial loads exist in the east near Perth Airport, along with commercial and industrial loads at Forrestfield and Midland Junction. Most supply south of the Northern Terminal is residential, with a mixture of commercial and light industrial loads. Towards the east, Darlington and Kalamunda substations consist of semi-rural connections supplying residential load.

13.2.2 Generation

There is no notable generation within the Metro North Region.

13.2.3 Existing Transmission Network Supply

The Metro North Region is a mix of 330 kV, 132 kV and 66 kV transmission voltages. The Northern Terminal is currently one of the largest load centres in the Western Power Network. The network in the area is characterised by strong 330 kV ties with generation centres in the south (from the Muja and Kwinana terminals) and north from the Neerabup Terminal, as well as 330 kV connections with large load supported by the Southern Terminal and Guildford Terminal. The network within the Northern Terminal is highly meshed, which can create considerable challenges as numerous contingencies in the area can generate power network security issues under some operating conditions.

There are three 132 kV transmission circuits connected to the Western Terminal that provide its supply, with overhead lines originating from the Northern, South Fremantle and East Perth terminals via the Cook Street Substation. Supply to substations from Western Terminal has been predominately achieved through an ageing 66 kV sub-transmission network. Western Power is investigating further opportunities to consolidate and convert assets to 132 kV over the medium term, where possible.

The transmission network in around the Guildford Terminal is connected to other major terminals, including the Northern Terminal by 330 kV and 132 kV transmission circuits, and the Southern Terminal by a 330 kV circuit. There are also 132 kV circuits connecting the Guildford, Muja and Merredin terminals. The 330 kV and 132 kV bus sections within the Guildford Terminal are connected via a single 490 MVA transformer that supports most of the demand in the area. Following an outage of this transformer, these loads rely on support from the Northern Terminal and other 132 kV injections from neighbouring regions.

13.2.4 Key Developments in the Region

The most notable developments in the Metro North Region are around the rapid increase in rooftop solar PV connection, which has created increasing challenges in operation of the power system during low demand conditions. These challenges are expected to increase as new rooftop solar PV connections into the SWIS increase at a steady rate over the next five years.

13.3 Network Performance

This section presents the network performance for the Metro North Region over the study period.

13.3.1 Thermal Capacity – Boundaries

The following assumptions were made in developing the import and export boundaries:

- Import boundaries consider peak demand and economic generation dispatch conditions.

Import Boundaries

Figure 45 shows the network import boundaries in the Metro North Region. These boundaries are defined using the worst contingency (↯) and the worst overload circuit (*) as shown in **Table 21**.

The expected transfer and transfer capacity for each of the import boundaries across the study period are shown in **Figure 46** to **Figure 48**.

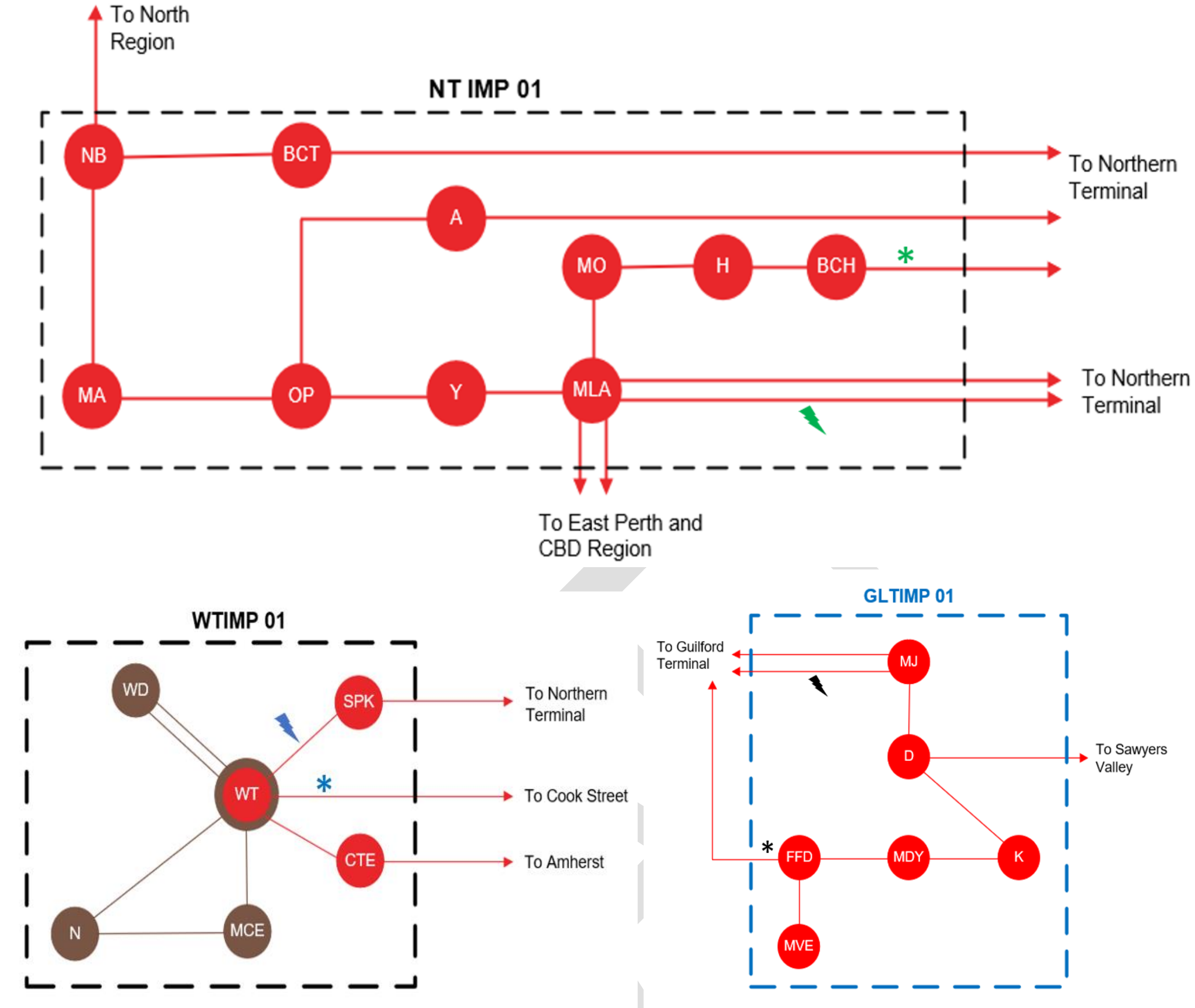

Figure 45: Network import boundaries in the Metro North Region

Table 21: Thermal import boundary characteristics – Metro North Region

Characteristics	Import Boundaries		
	WTIMP 01	**NTIMP 01**	**GLTIMP 01**
Worst contingency	Northern Terminal – Shenton Park 81	Northern Terminal – Mount Lawley 82	Guildford – Midland Junction 82
Contingency type	N-1	N-1	N-1
Worst circuit/s	Western Terminal – Cook St 81	Northern Terminal – Beechboro 81	Guildford – Midland Junction 81

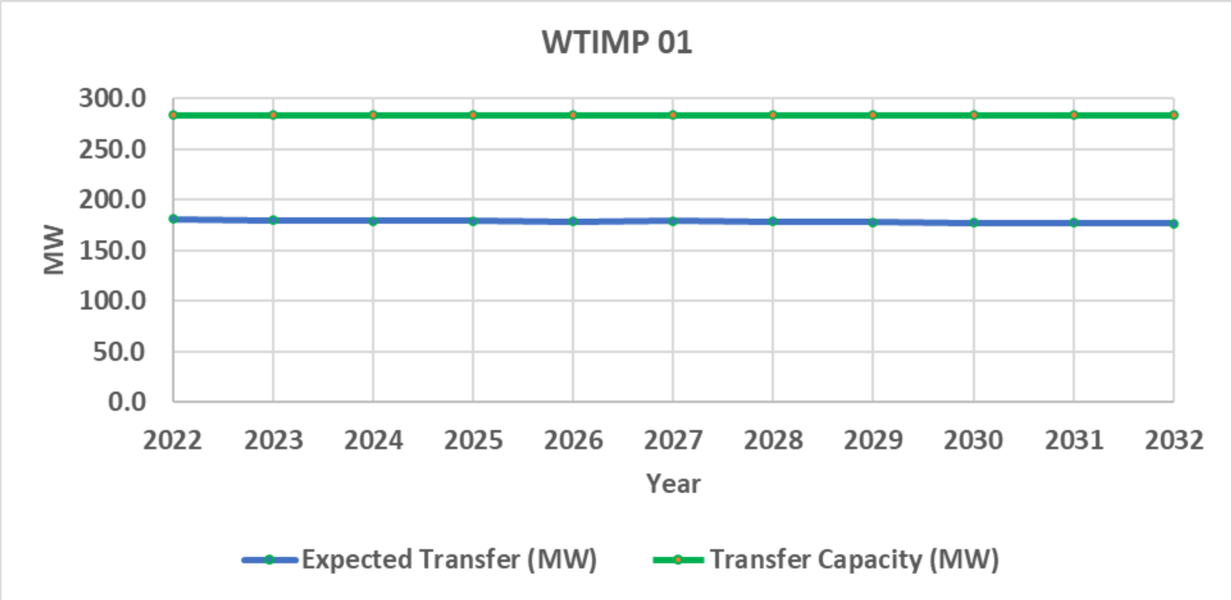

Figure 46: Expected transfer and transfer capacity in WTIMP 01 boundary – peak demand

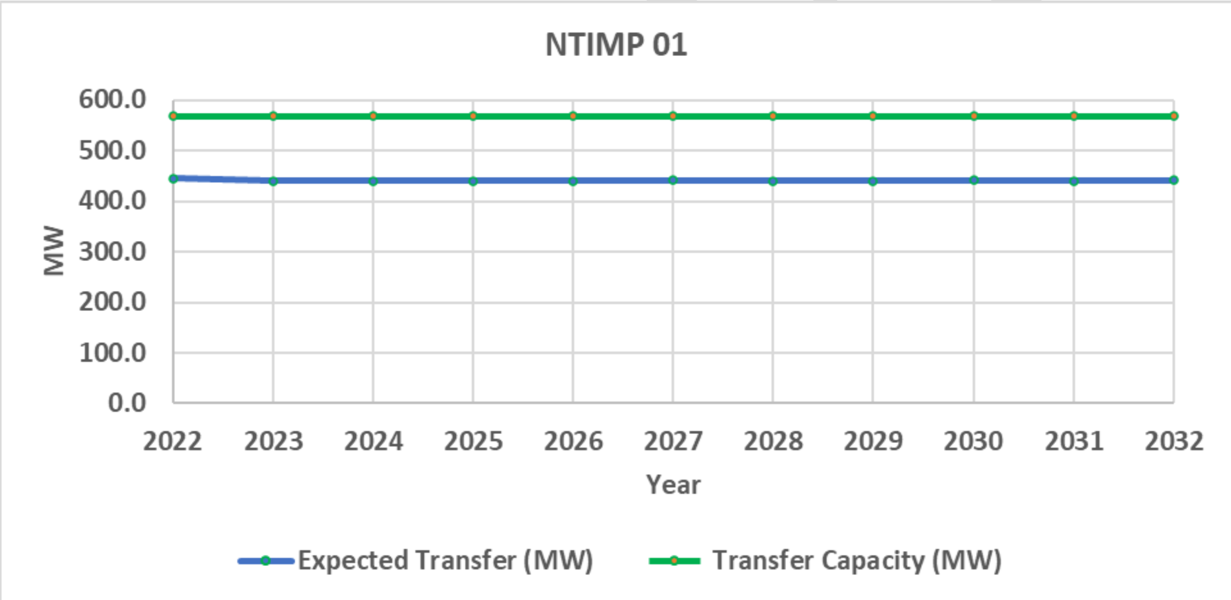

Figure 47: Expected transfer and transfer capacity in NTIMP 01 boundary – peak demand

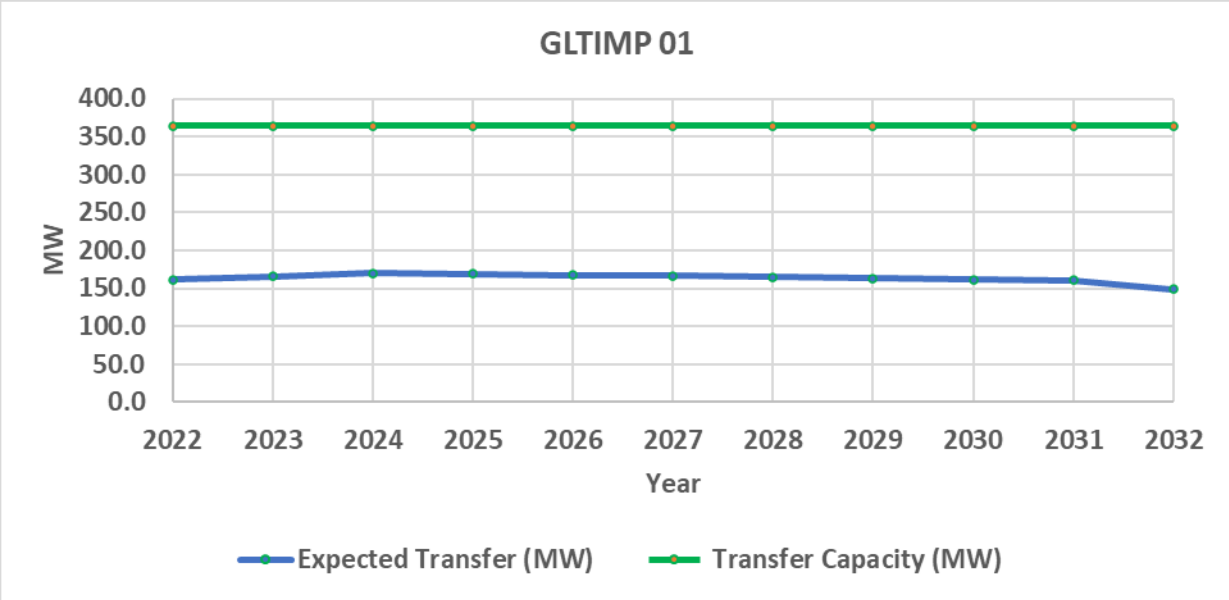

Figure 48: Expected transfer and transfer capacity in GLTIMP 01 boundary – peak demand

The above figures highlight that there is available capacity throughout all Metro North Region boundaries, however limited capacity to connect new load connections in the NT IMP 01 import boundary as expected transfers increase over the study period. The GLT IMP 01 import boundary has considerable available spare capacity, making it a suitable location to accommodate demand increases in the area.

13.3.2 Thermal Capacity – Transmission Lines

There are no thermal line performance constraints for the Metro North Region.

13.3.3 Thermal Capacity – Transformers

This section shows the existing and forecast peak load utilisation across the period 2023/24 to 2032/33 for all zone substations operated by Western Power within the Metro North Region.

Table 22: Utilisation legend (for Table 23)

LEGEND	Classification Name	Utilisation %
	Under utilised	below 40%
	Medium utilisation	>40% & 75%
	Highly utilised	>75% & 95%
	Over utilised	above 95%

Table 23: Metro North Region Zone Substation utilisation heat map[39]

Substation	Capacity	Actual Utilisation (%)	Forecast Utilisation (%)																				Mitigation
	MVA	2022	2024		2025		2026		2027		2028		2029		2030		2031		2032		2033		
			PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	
Arkana	72	76	78	73	79	73	80	74	81	75	82	77	84	79	86	81	88	83	90	85	93	88	
Balcatta	53	31	38	32	38	31	37	30	37	30	37	31	38	31	38	31	37	31	37	31	38	32	
Beechboro	86	79	82	77	83	78	84	79	85	80	87	81	88	83	90	85	92	87	94	88	96	91	
Cottesloe	54	80	93	82	92	81	92	81	93	82	95	84	96	85	97	86	97	86	98	87	100	89	
Darlington	48	47	50	45	50	45	50	45	51	46	51	46	52	47	52	48	53	48	54	49	55	50	
Forrestfield	80	37	39	38	39	38	40	38	40	39	40	39	41	40	41	40	42	40	42	41	43	42	
Hadfield	77	69	73	67	73	67	73	67	73	68	74	68	74	69	75	69	76	70	76	71	78	72	
Hazelmere	27	94	104	91	104	91	105	92	105	92	106	93	107	94	108	95	109	96	110	97	111	98	Managed by distribution transfers
Henley Brook[40]	53	124	135	130	139	134	143	138	149	144	156	151	162	158	168	163	173	169	179	174	186	182	Additional transformer (Scoping, estimated in service by FY2025/26)
Kalamunda	77	49	52	47	52	48	53	48	53	48	54	49	55	50	56	51	57	52	57	53	59	54	
Malaga	81	50	54	50	55	50	56	51	56	51	57	52	57	53	58	54	59	54	60	55	61	56	
Manning Street	43	83	82	74	82	74	83	74	84	76	87	78	89	80	90	82	92	83	93	85	96	88	
Medical Centre	83	61	65	58	66	58	66	58	66	59	66	59	66	59	66	59	66	59	66	59	67	59	

39 The Mount Lawley and Nedlands substations are not included in the above table. Mount Lawley 132 kV substation is a switchyard. Nedlands 66 kV substation has been de-energised.

40 Western Power is developing contingency plans to manage the substation capacity shortfall risks prior to the installation of an additional transformer

Substation	Capacity	Actual Utilisation (%)	Forecast Utilisation (%)																				Mitigation
	MVA	2022	2024		2025		2026		2027		2028		2029		2030		2031		2032		2033		
			PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	
Midland Junction	94	66	75	65	76	67	77	68	79	69	80	71	81	72	83	74	84	75	86	77	88	79	
Morley	79	72	78	72	78	72	78	72	79	73	81	75	83	77	85	79	86	80	87	81	90	84	
Munday	54	40	44	42	43	42	43	42	44	42	44	42	44	42	43	42	43	42	44	42	44	42	
North Beach	75	85	89	76	90	75	90	74	91	75	92	76	94	78	95	79	96	80	98	81	100	83	Replacement transformer project provides increased capacity
Osborne Park	63	83	95	91	96	92	96	92	95	91	94	89	93	88	92	88	91	87	90	86	90	86	
Shenton Park	71	78	78	73	77	72	78	73	79	74	80	75	81	76	82	77	82	78	84	80	86	82	
Wembley Downs	43	88	102	84	103	85	104	86	105	87	106	88	107	89	108	90	110	91	111	93	113	94	Managed by distribution transfers
Yokine	70	83	74	69	72	68	71	69	72	70	74	71	75	73	77	75	78	76	80	78	83	81	

13.3.4 Steady State Voltages

There are no voltage-related performance constraints within the Metro North Region over the study period.

13.3.5 Fault Levels

The Northern Terminal is a particularly congested site with numerous 330 kV and 132 kV transmission line connections. Under current network configurations during high demand conditions, fault levels can become problematic and 132 kV disconnectors at Mount Lawley can become under fault rated under certain operating conditions. Western Power has addressed these limitations by operating the Mount Lawley Substation 132 kV buses split under some operating conditions.

13.3.6 Stability

There are no stability-related performance constraints within the Metro North Region over the study period.

13.3.7 Reliability

There are no reliability-related performance constraints within the South Region over the study period.

13.3.8 Asset

Existing asset performance constraints were identified in the Metro North Region within the study period, including:

- A number of zone and terminal substation transformers in degraded condition require mitigation within the study period, including:
    - Arkana – 132/22 kV 33 MVA/27 MVA – T1 & T3
    - Darlington – 132/22 kV 10 MVA – T1
    - Hadfield – 132/22 kV 27 MVA – T1
    - Kalamunda – 132/22 kV 33 MVA – T3
    - Midland Junction – 132/22 kV 30 MVA – T1 & T2
    - North Beach– 132/22 kV 27 MVA – T1 & T3
    - Northern Terminal – 330/132 kV 490 MVA – T1 & T2
    - Osborne Park– 132/11 kV 27 MVA – T1
    - Wembley Downs – 132/11 kV 27 MVA/ 32 MVA – T1 & T4
    - Western Terminal – 132/66 kV 100 MVA – T1 & T2
- The 11 kV switchboards at Manning Street and the 22 kV Hadfield's switchboards are in degraded condition and need to be addressed in the next 10 years.

13.4 Network Augmentation Works

Completed and committed transmission projects in the Metro North Region are shown in **Table 24**.

Table 24: Completed and Committed Projects – Metro North Region

Project	Scope	Benefits of project	Network driver/s	By when	Lifecycle Status
Yokine: Switchboard replacement	Replacement of the existing 11 kV indoor switchboard at Yokine substation.	Address degraded asset condition issues	Asset Condition	FY2023/24	Completed
North Beach Substation: Transformer replacement	Replace the existing 132/22 kV,27 MVA T3 transformer with a new 33 MVA unit.	Address degraded asset condition issues and accommodate increasing demand in the area.	Asset Condition	FY2023/24	Execution
Nedlands Substation: Decommissioning	Removal of redundant 66 kV assets and partial removal of the Western Terminal – Nedlands 66 kV supplies at the existing 66 kV Nedlands Substation.	Address degraded asset condition issues	Asset Condition	FY2024/25	Execution
Manning St Substation: Switchboard and relay room replacement and new relay room	Replacement of the existing 11 kV indoor switchboard and relay room at Manning St Substation.	Address degraded asset condition issues	Asset Condition/ Growth – Thermal	FY2025/26	Execution
Osborne Park Substation: Transformer replacement	Replace the existing 132/22 kV, 27 MVA T1 transformer with a new 33 MVA unit.	Address degraded asset condition issues and accommodate increasing demand in the area.	Asset Condition	FY2024/25	Planning
Henley Brook Substation: New Transformer	Installation of a third 132/22 kV 33 MVA transformer at Henley Brook Substation	Address substation capacity shortfall and accommodate increasing demand in the area.	Growth – Thermal	FY2025/26	Scoping

13.5 Network Opportunities

This section highlights possible network opportunities and network solutions in the Metro North Region over the study period. These opportunities will be explored further during the scoping and planning phases of the project lifecycle. If the opportunities are not a technically and economically viable, network solutions will be implemented to address the identified network constraints.

Table 25: Network Opportunities projects – Metro North Region

Location	Scope/Issue	Market Opportunity	By when	Lifecycle Status	Proposed Network Solution
Henley Brook	Transformer thermal overloads	Reduce the demand supplied by Henley Brook Substation during peak demand conditions to potentially reduce or defer network augmentation to increase the power transfer capacity to the area.	FY2026/27	Initiation	Henley Brook Substation: Fourth Transformer
WT IMP 01, NT IMP 01 and GLT IMP 01 available import capacity	Spare available import capacity exists over a number of import boundaries within the Metro North Region.	An opportunity exists to utilise spare available capacity within WT IMP 01, NT IMP 01 and GLT IMP 01 import boundaries by increasing demand of existing loads or via the connection of new loads	Across the study period	Initiation	N/A

13.6 Emerging Issues and Drivers

The Metro North Region is predominately a load centre. As shown in section 13.3.1, most parts of the region have available spare capacity to connect additional load connections, without triggering the need for network augmentation.

The 66 kV networks supplied from the Western Terminal require mitigation in the next 10 to 20 years and Western Power is investigation options to either retire or upgrade these supplies to 132 kV as they approach their end of service life.

Although the progressive retirement of coal units at Muja and Collie represents a material change to the SWIS, the Metro North Region is predominately a load centre and is expected to be less impacted than other regions. Upgrades at the Northern and Guildford terminal are anticipated to support likely bulk power flows, particularly as industries look to decarbonise.

Western Power is working with industry to better understand how the proliferation of EVs will impact the network in the Metro North Region. Due to the high density of load in this region (particular along river and coastal areas), increased EV usage is likely to trigger the need to increase capacity on the transmission system. This may create challenges with service congestion, scarcity of available land, construction of new transmission lines and substations, as well environmental and community approvals.

14. Metro South Region

14.1 Geography

The Metro South Region covers a large area, including most of the urban Perth metropolitan networks south of the river, from the Cannington Terminal in the east to the Southern and South Fremantle Terminal towards the west. The region also covers the southern metropolitan coastal strip from Kwinana through to Rockingham and Mandurah and extends east to encompass the Pinjarra Substation. The network diagram for this region is split across Figure 49 and Figure 50 for illustration purposes only.

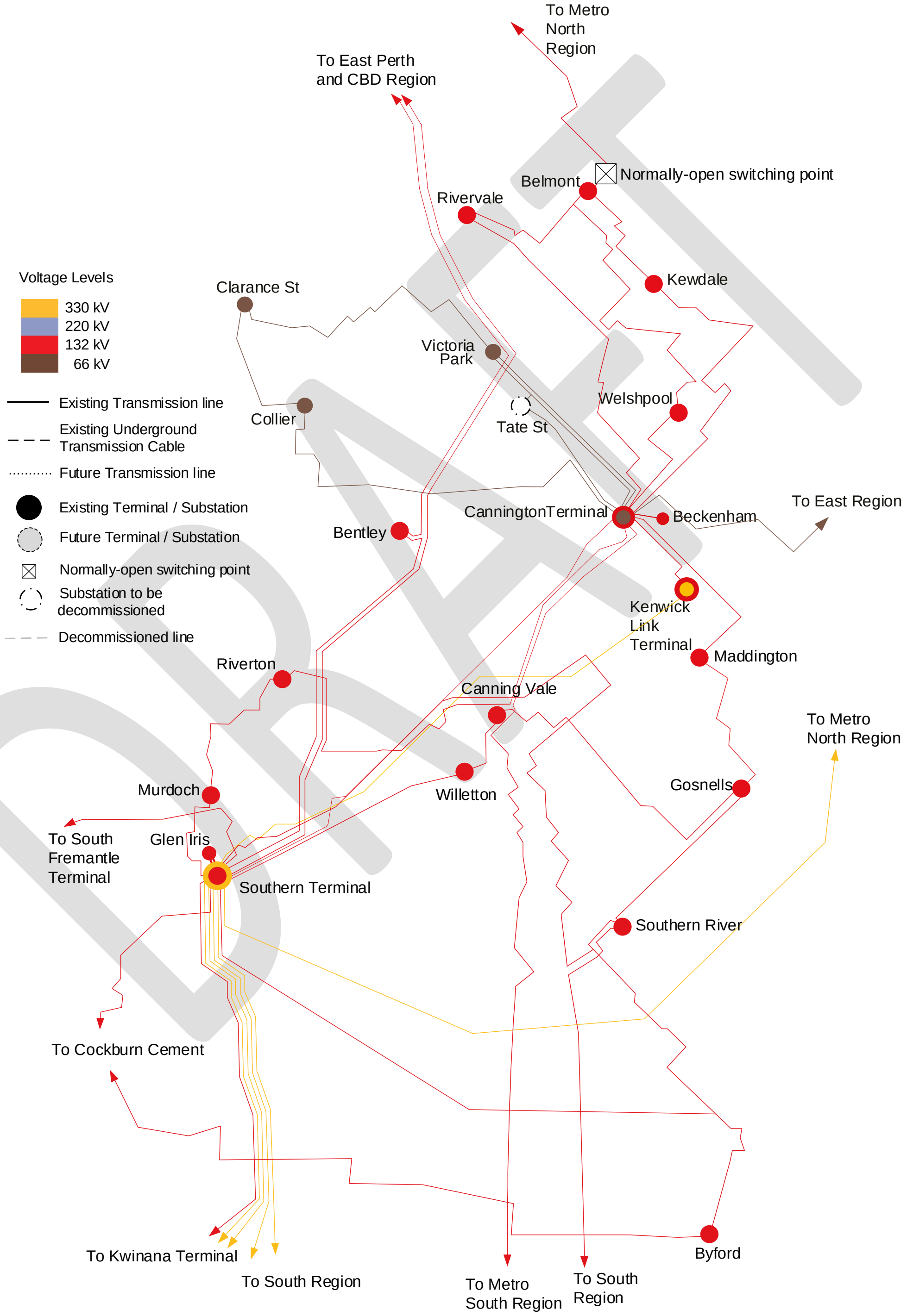

Figure 49: Western Power's Metro South Region (Part A) – Network Diagram

Figure 50: Western Power's Metro South Region (Part B) – Network Diagram

The Metro South Region consists of five terminals – South Fremantle, Kwinana, Southern, Cannington and Kenwick Link - and 31 zone substations owned and operated by Western Power. The other transmission sites in the Metro South Region are customer-owned substations.

Terminal

- Kwinana Terminal - 330/132/66 kV
- South Fremantle Terminal – 132/66 kV
- Southern Terminal – 330/132 kV
- Cannington Terminal - 132/66 kV
- Kenwick Link Terminal - 330/132 kV

Zone Substations / WP Substations

- Amherst – 132/22 kV
- Australian Paper Mills – 66/22 kV
- Beckenham – 132/22 kV
- Belmont – 132/22 kV
- Bentley – 132/22 kV
- Bibra Lake – 132/22 kV
- Byford 132/22 kV
- Canning vale – 132/22 kV
- Clarence St – 66/11 kV
- Collier – 66/11 kV
- Cockburn Cement – 132/22 kV
- Edmund Street – 66/11 kV
- Glen Iris – 132/22 kV
- Gosnells – 132/22 kV
- Kewdale – 132/22 kV
- Maddington – 132/22 kV
- Mandurah – 132/22 kV
- Mason Road – 132/22 kV
- Medina – 132/22 kV
- Meadow Springs – 132/22 kV
- Murdoch – 132/22 kV
- Myaree – 66 /22 kV
- O'Connor – 66/22 kV
- Pinjarra – 132/22 kV
- Rivervale – 132/22 kV
- Riverton – 132/22 kV
- Rockingham – 132/22 kV
- Southern River 132/22 kV
- Tate Street – 66/22 kV
- Victoria Park – 66/11 kV[41]
- Waikiki – 132/22 kV
- Welshpool – 132/22 kV
- Willetton – 132/22 kV

Customer substations

- Alcoa Kwinana – 132 kV
- Australian Fused Materials 132 kV
- Beckenham – 132 kV
- British Petroleum – 66 kV
- Broken Hill – 66 kV
- CSBP – 132 kV
- Cockburn Cement Limited – 132 kV
- Cockburn Power Station – 132 kV
- Glen Iris – 132 kV
- Kerr McGee Kwinana – 132 kV
- Kwinana Donaldson Road – 132 kV
- Kwinana Desalination Plant – 132 kV
- Kwinana Power Partnership – 132 kV
- Leath Road – 132 kV
- Office Road – 132 kV
- Parklands 132 kV
- Tianqi Lithium Australia – 132 kV
- Western Mining 132 kV

[41] VP substation is now a 66kV Switchyard

14.2 Regional Characteristics

14.2.1 General

The Metro South Region covers the southern suburbs, which supplies a diverse mixture of residential, commercial and light/heavy industrial load. It also includes popular tourist spots, Fremantle and Mandurah. Most residential load is supplied out of the Southern Terminal, parts of Cannington and the South Fremantle Terminal and the Mandurah area. Large light/heavy industrial load areas are supported in the east of the region and to the west providing supply to Fremantle Port. The Kwinana area has historically been a site for generation connections and plays a significant role in State development by supporting large scale heavy industry and presenting attractive opportunities for future developments.

14.2.2 Generation

The Kwinana Terminal area is a key supply point for the rest of the Western Power Network, with a number of high-capacity supplies at both 132 kV and 330 kV. The strength of the network, coupled with the availability of gas fuel resources, has created a strong attraction for new generation entrants to be sited in the area. As Western Power continues to receive considerable interest for new entrant generation developments, Kwinana is likely to remain as a key generation hub into the foreseeable future.

14.2.3 Existing Transmission Network Supply

The Kwinana and Southern terminals share large bulk supplies on both the 132 kV and 330 kV networks, with the Southern Terminal a key focal point of supply into the Perth metropolitan area. In addition, a number of 66 kV loops within the South Fremantle, Cannington and Kwinana regions are nearing their end of service life.

The Metro South Region consists of five bulk terminals which supply zone substations via 330 kV, 132 kV and 66 kV sub-transmission networks. Due to the highly meshed nature of 132 kV transmission network in this region, the 132 kV network has become over-utilised in certain parts, while the 330 kV network remains under-utilised.

14.2.4 Key Developments in the Region

A number of new developments in the Kwinana area have resulted in two new 132 kV substations, Office Road Substation and Leath Road, that have supported a waste-to-energy generation connection and a lithium processing load connection. Furthermore, Synergy's 100 MW/ two-hour large-scale battery connection is operational (with plans for Stage 2 by 2024/25) and will support integration of more renewable energy and improve grid stability.

14.3 Network Performance

This section presents the network performance for the Metro South Region over the study period.

14.3.1 Thermal Capacity – Boundaries

The following assumptions were made in developing the import and export boundaries:

- Import boundaries consider peak demand and security constrained and economic dispatch conditions
- Export boundaries consider peak demand and maximum generation dispatch conditions (within boundary)
- The KW T1 bus tie transformer is out of service.

Import Boundaries

Figure 51 and **Figure 52** show the network import boundaries in the Metro South Region. These boundaries are defined using the worst contingency (↯) and the worst overload circuit (*) as shown in **Table 26**.

The expected transfer and transfer capacity for each of the import boundaries across the study period are shown in **Figure 53** to **Figure 56**.

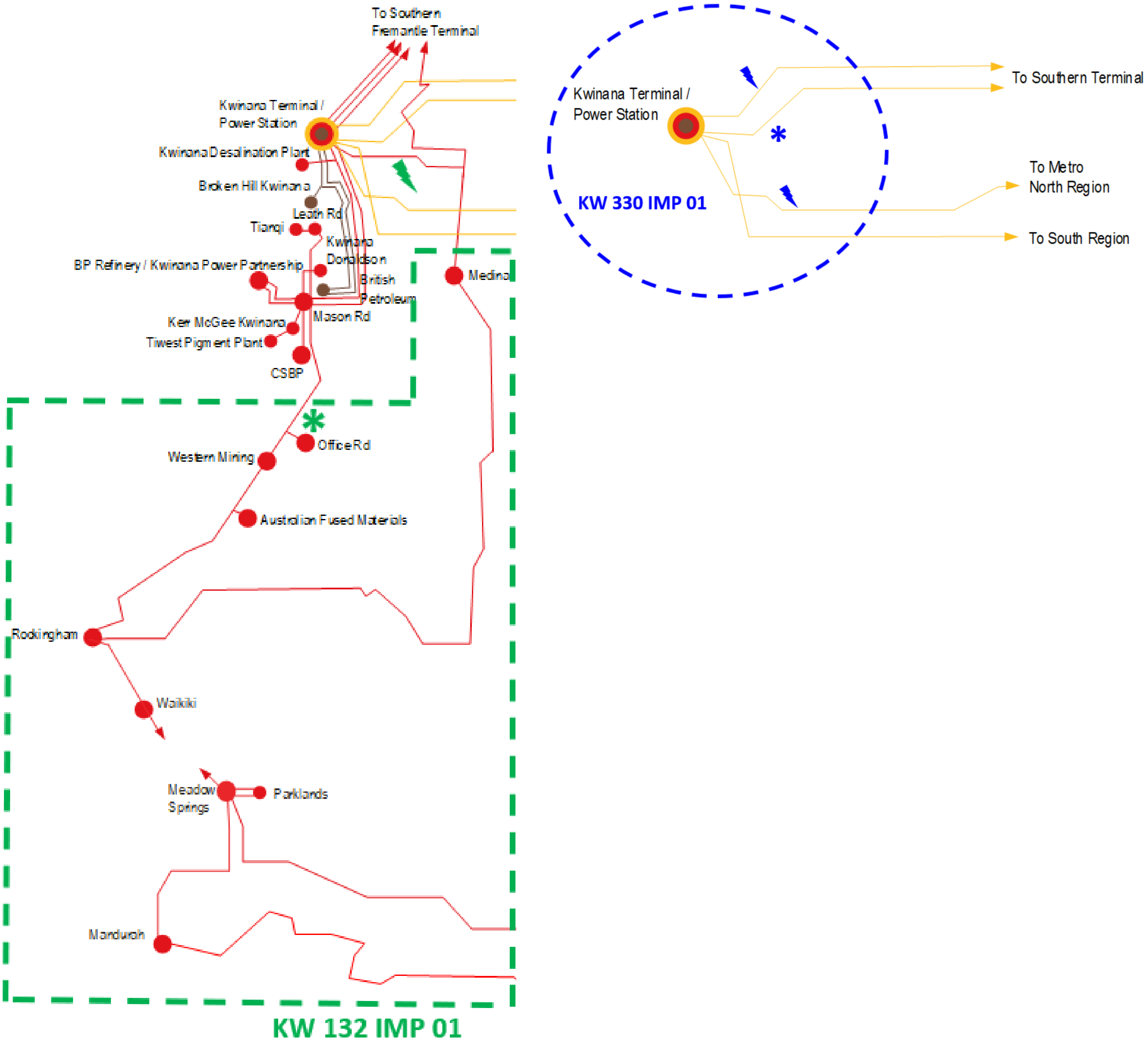

Figure 51: Network import boundaries in the Metro South Region – Kwinana 330 kV and 132 kV

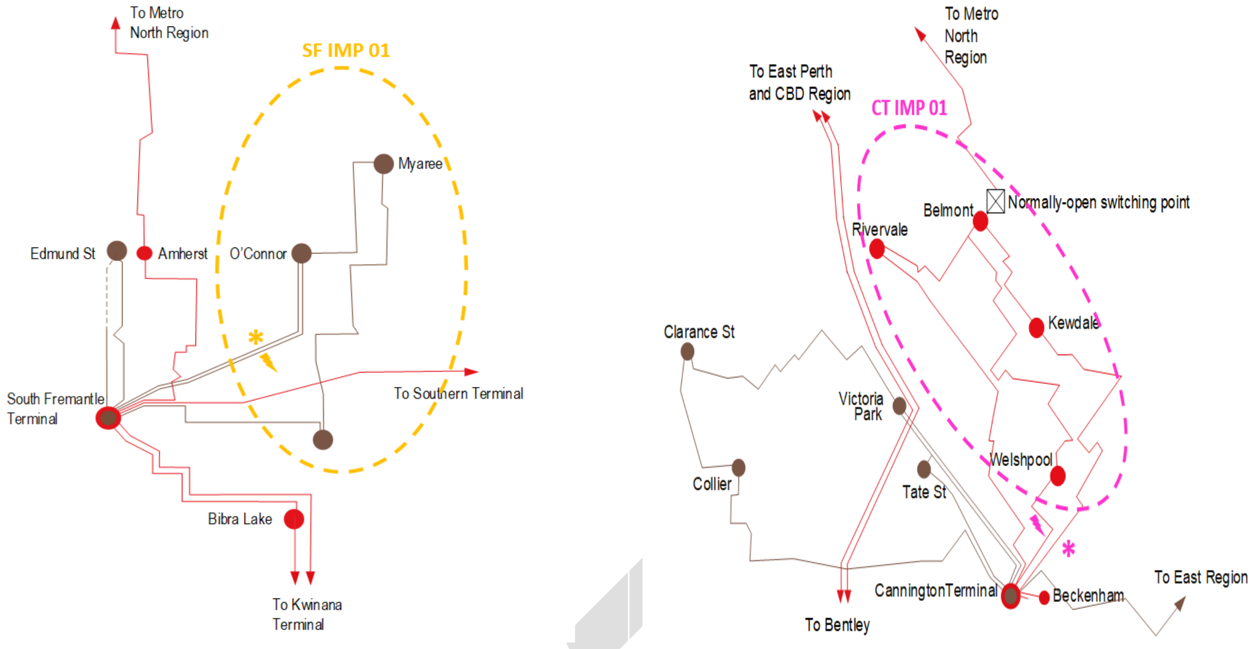

Figure 52: Network import boundaries in the Metro South Region – South Fremantle and Cannington

Table 26: Thermal import boundaries characteristics – Metro South Region

Characteristics	Import Boundaries			
	KW330IMP 01	**KW132IMP 01**	**SFIMP 01**	**CTIMP 01**
Worst contingency	Kwinana – Southern Terminal 92 and Kwinana-Kemerton/Oakley 91	Medina-Cockburn Cement/Kwinana 81	South Fremantle - O'Connor 71	Cannington Terminal - Welshpool 81
Contingency type	N-1-1	N-1	N-1	N-1
Worst circuit/s	Kwinana – Southern Terminal 91	Mason Rd – Western Mining 81	South Fremantle-O'Connor 72	Cannington Terminal – Kewdale 81

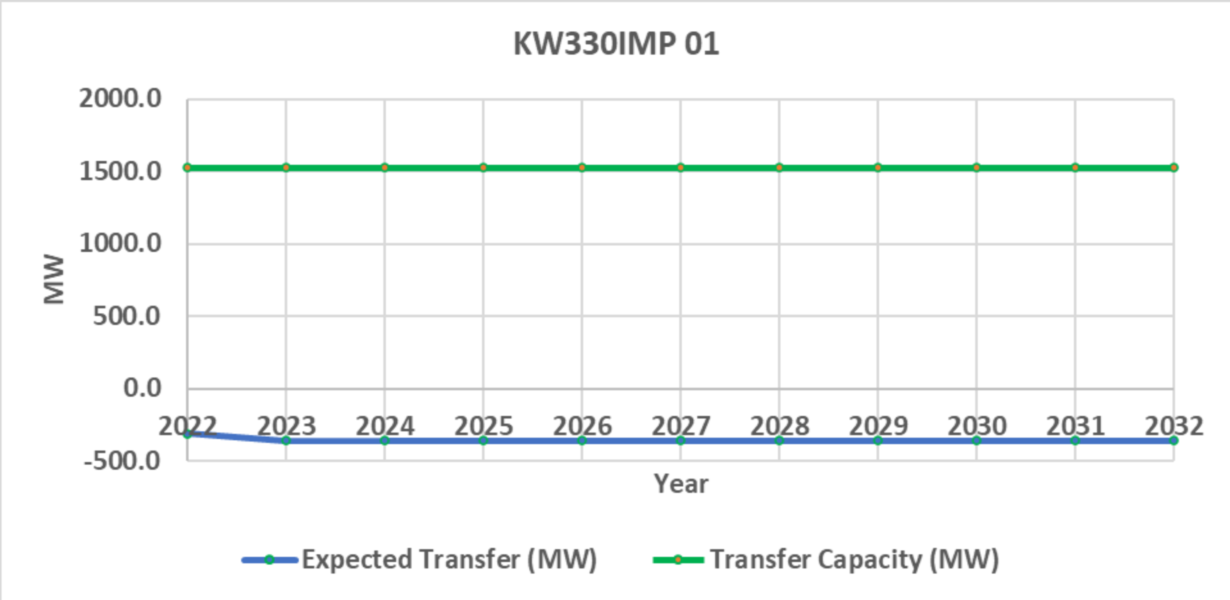

Figure 53: Expected transfer and transfer capacity in KW330IMP 01 boundary – peak demand

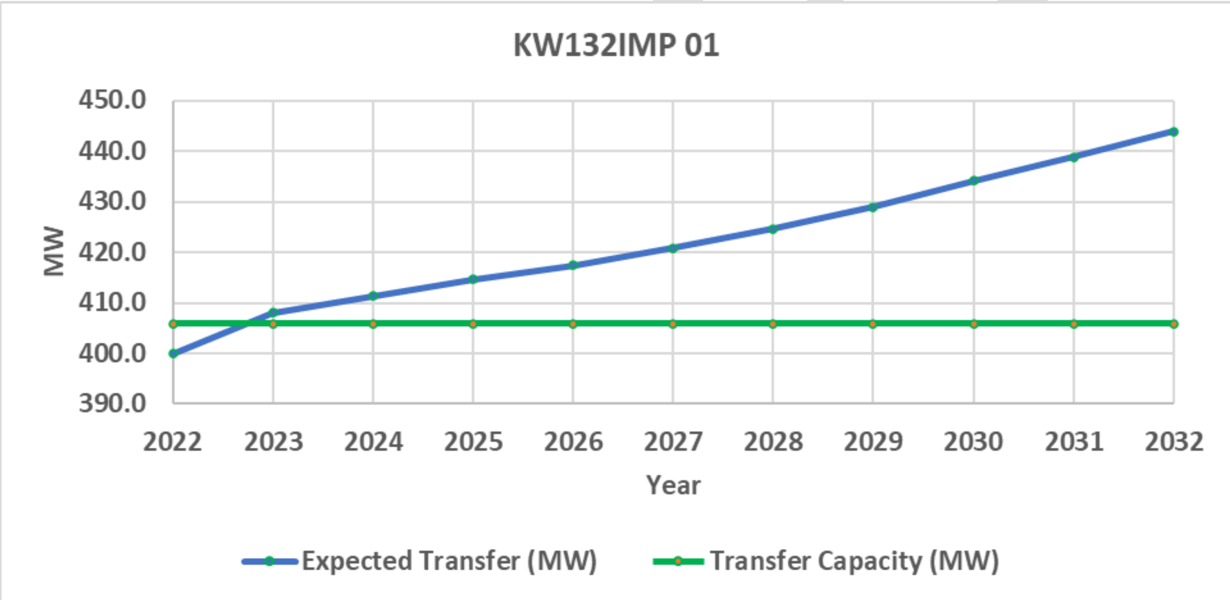

Figure 54: Expected transfer and transfer capacity in KW132IMP 01 boundary – peak demand

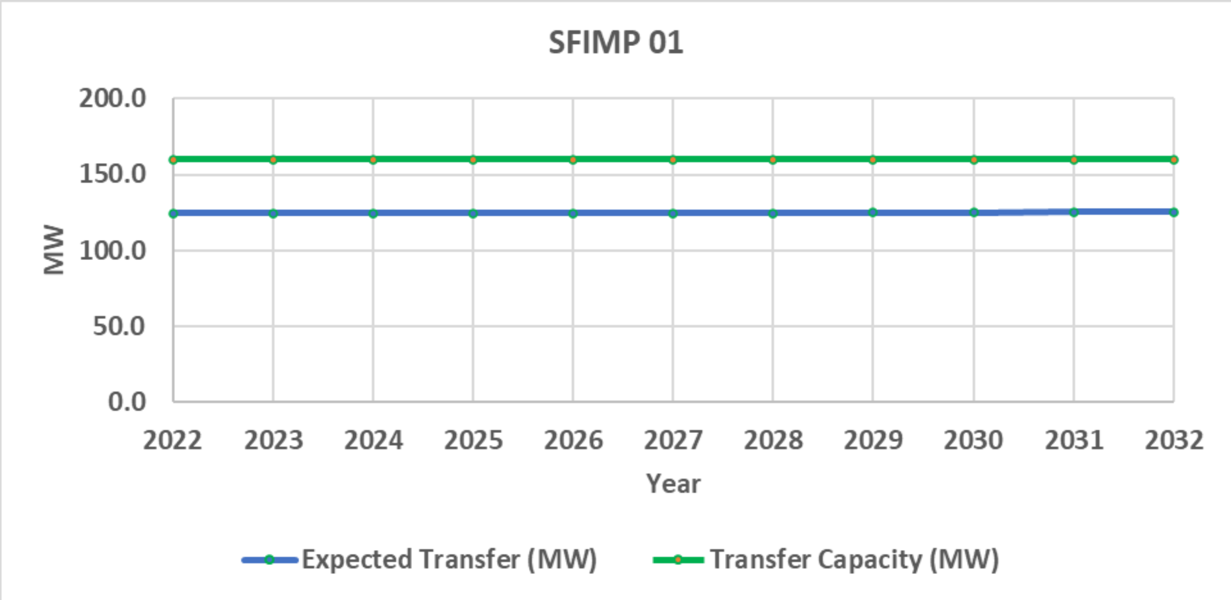

Figure 55: Expected transfer and transfer capacity in SFIMP 01 boundary – peak demand

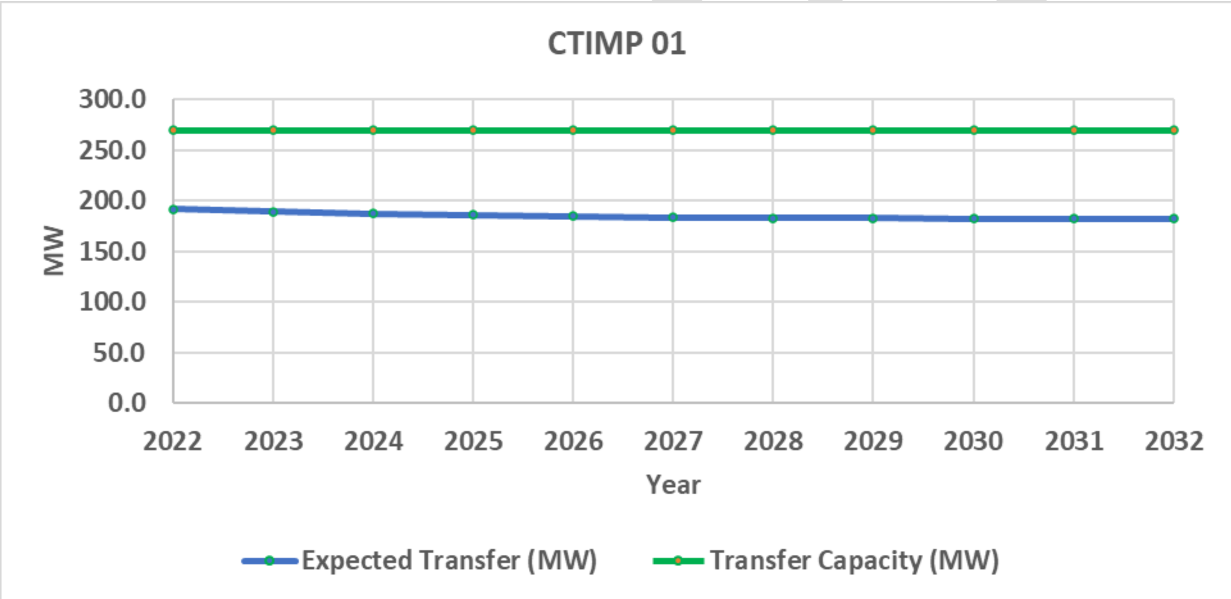

Figure 56: Expected transfer and transfer capacity in CTIMP 01 boundary – peak demand

As observed in the above figures, the KW 330 IMP boundary is a net exporter of power during peak demand periods. Under N-1-1 conditions there is approximately 1800 MW of available transfer capacity, making it a suitable candidate to support new large block load connections at 330kV.

The available capacity in the KW 132 IMP 01 boundary is exceeding capacity as residential loads are expected to grow in the future. New reference load connections likely to require network augmentation works. This area could benefit from alternative solutions to manage peak load periods.

The SFIMP 01 and CTIMP 01 import boundaries have available capacity to accommodate increasing and new load connections.

Export Boundaries

Figure 57 shows the network import boundaries in the Metro South Region. These boundaries are defined using the worst contingency (↯) and the worst overload circuit (*) as shown in **Table 27**.

The expected transfer and transfer capacity for each of the import boundaries across the study period are shown in **Figure 58** to **Figure 59**.

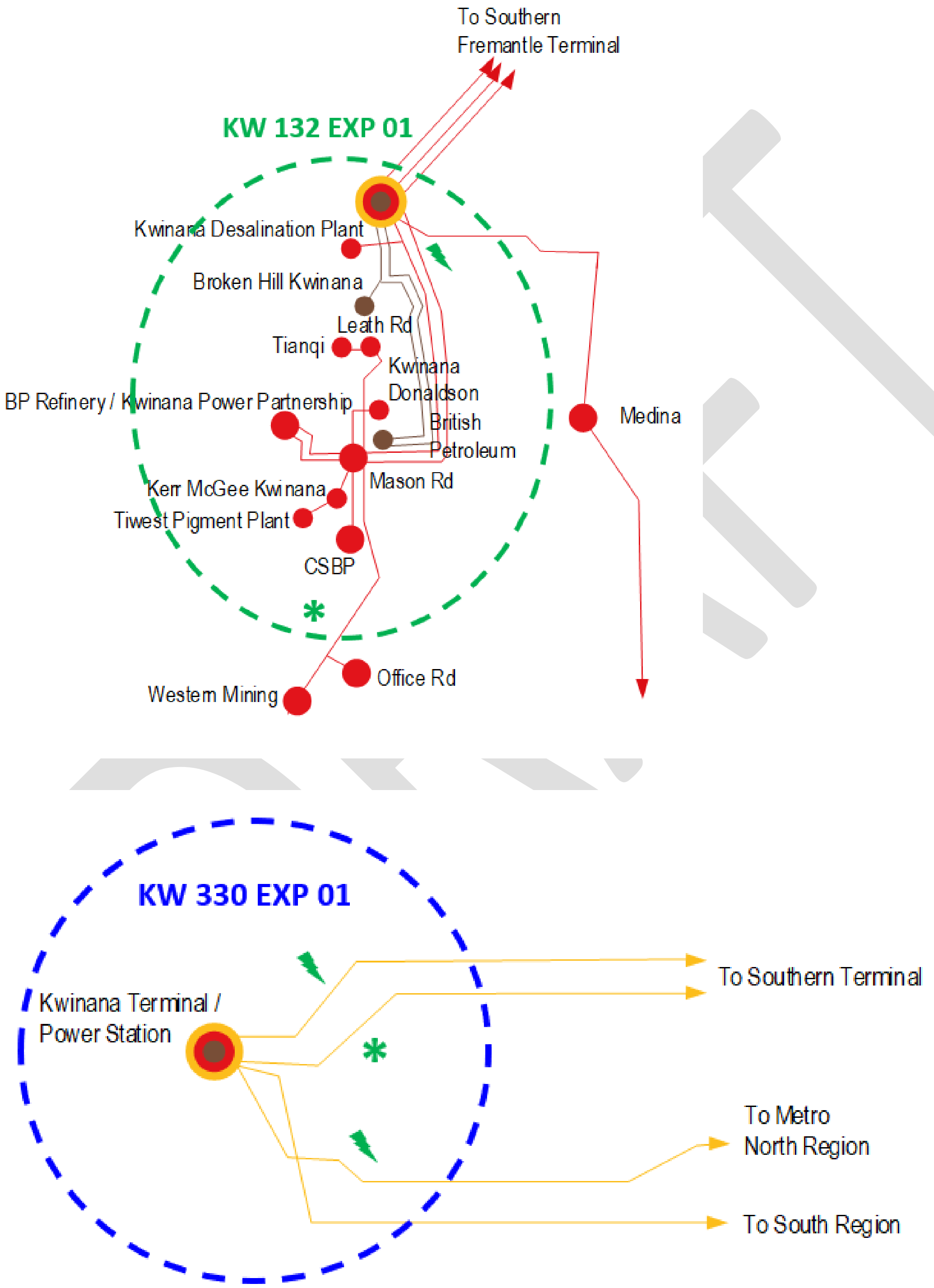

Figure 57: Network export boundaries in the Metro South Region

Table 27: Thermal export boundaries characteristics – Metro South Region

Characteristics	Export Boundaries	
	KW330EXP 01	**KW132EXP 01**
Worst contingency	Kwinana – Southern Terminal 92 and Kwinana-Kemerton/Oakley 91	Kwinana-Cockburn Cement/Medina 81
Contingency type	N-1-1	N-1
Worst circuit/s	Kwinana – Southern Terminal 91	Mason Road – Western Mining 81

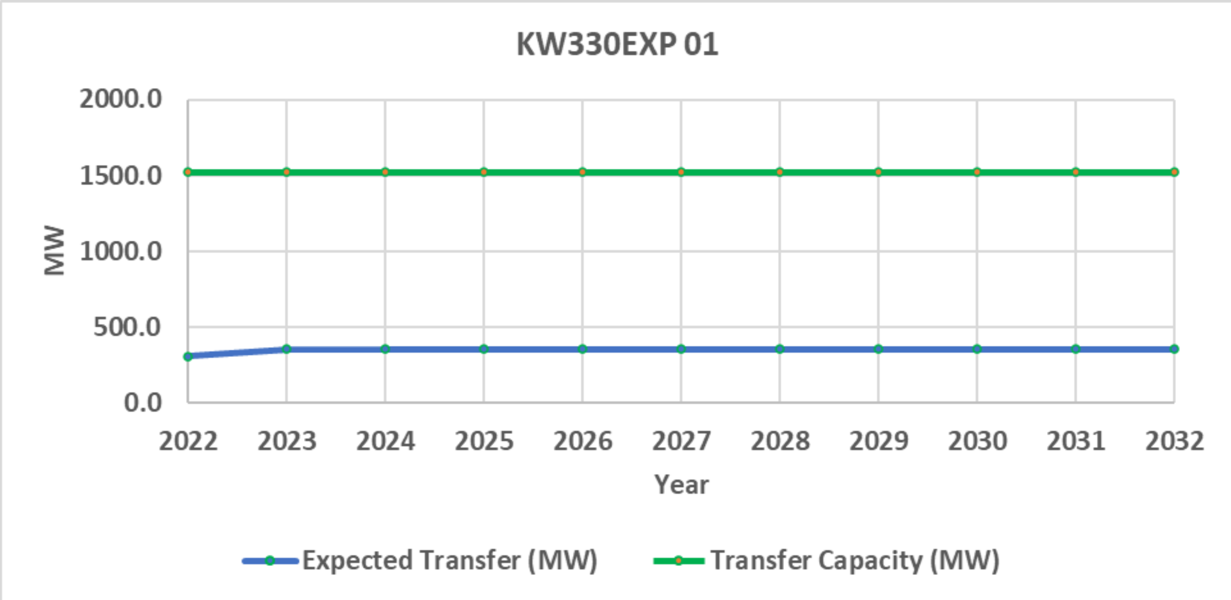

Figure 58: Expected transformer and transfer capacity in KW330EXP 01 boundary – peak demand

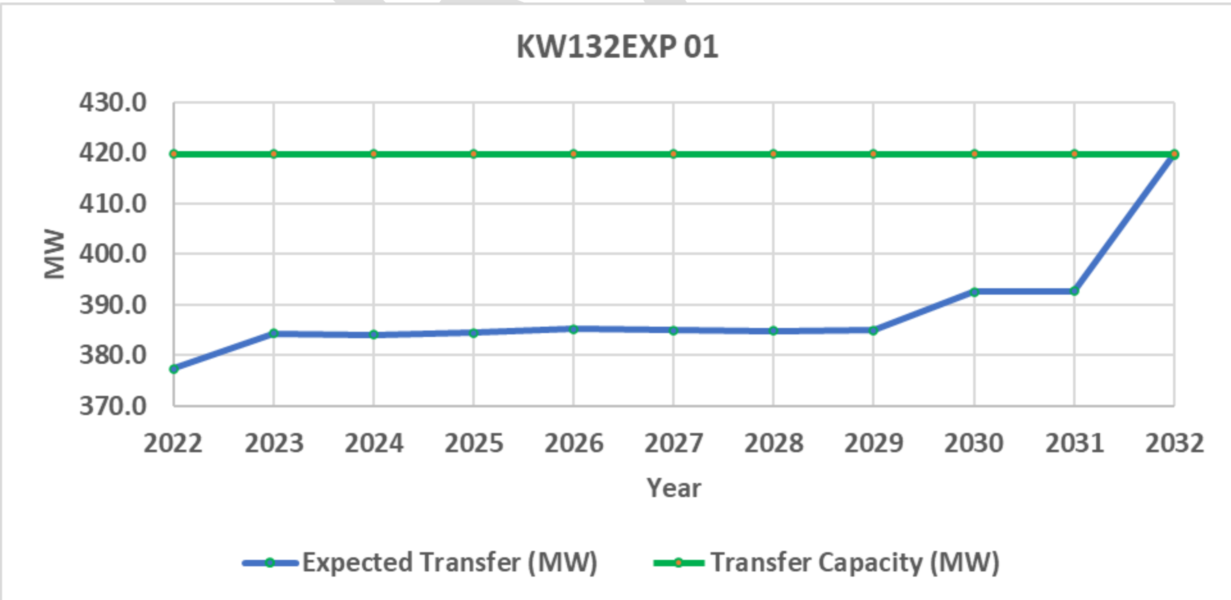

Figure 59: Expected transfer and transfer capacity in KW132EXP 01 boundary – peak demand

Under N-1-1, the KW330EXP 01 export boundary has almost 1200 MW of available capacity, which makes it a suitable candidate to connect new large-scale generation. The Kwinana 132 kV export boundary (KW132EXP 01) has very limited available capacity over the study period and would require potential network augmentation to facilitate new generation connections.

14.3.2 Thermal Capacity – Transmission Lines

Post contingent thermal overloads arise during peak demand conditions within the Metro South Region over the study period on the following circuits:

- Mandurah to Pinjarra 132 kV line overloads occur by 2022/23 and increases up to 112 per cent, following the loss of the Cannington Terminal to Meadow Springs/Pinjarra 132 kV line.
- Pinjarra to Alcoa Pinjarra 132 kV line overloads occur by 2022/23 and increases up to 108 per cent, following the loss of the Rockingham to Waikiki 132 kV line.

14.3.3 Thermal Capacity – Transformers

This section shows the existing and forecast peak load utilisation across the period 2023/24 to 2032/33 for all zone substations operated by Western Power within the Metro South Region.

Table 28: Utilisation legend (for Table 29)

LEGEND	Classification Name	Utilisation %
	Under utilised	below 40%
	Medium utilisation	>40% & 75%
	Highly utilised	>75% & 95%
	Over utilised	above 95%

Table 29: Metro South Region Zone Substation utilisation heat map

Substation	Capacity	Actual Utilisation (%)	Forecast Utilisation (%)																				Mitigation
	MVA	2023	2024		2025		2026		2027		2028		2029		2030		2031		2032		2033		
			PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	
Amherst	85	76	83	70	83	70	84	70	84	71	85	72	86	74	87	75	87	75	88	76	90	78	
Australian Paper Mills	46	53	69	65	70	66	71	67	72	68	73	69	74	70	75	71	76	72	77	74	79	75	
Belmont	72	62	70	63	71	64	71	64	72	65	71	64	71	64	71	64	71	64	71	64	72	65	
Bentley	56	62	69	50	70	51	71	52	74	55	78	59	81	62	83	64	86	67	88	69	92	73	Load transfer from TT (completed)
Bibra Lake	56	106	107	92	109	94	111	96	112	97	114	99	116	101	118	103	119	104	121	106	124	109	Managed by distribution transfers Additional transformer option to be investigated
Byford[42]	77	106	116	105	118	107	121	110	124	114	129	118	133	122	136	125	139	128	142	131	147	136	Additional transformer (estimated in service by FY2025/26)
Cockburn Cement	77	65	65	59	66	60	67	61	67	62	68	63	69	63	70	64	71	65	72	66	73	68	
Clarence St	43	68	71	64	70	63	69	62	68	61	69	61	70	61	71	61	72	62	73	63	75	64	
Collier	69	65	75	63	74	62	73	61	72	60	72	61	73	61	73	61	72	60	72	60	73	61	
Canning Vale	93	66	71	68	73	70	75	72	76	73	77	74	79	76	81	78	83	80	85	82	87	84	
Edmund St	43	59	71	63	71	63	71	63	71	62	70	62	70	62	70	62	70	62	71	62	71	63	
Gosnells	77	87	89	82	90	83	90	84	91	84	92	86	93	87	95	89	96	90	98	92	100	94	
Kewdale	56	59	75	62	76	62	75	61	74	60	73	59	73	59	73	59	73	59	73	59	73	59	Load transfer from TT (completed)
Maddington	26	115	107	95	108	95	108	96	109	97	111	99	113	101	115	102	116	104	117	105	120	107	Managed by distribution transfers

42 Western Power is developing contingency plans to manage the substation capacity shortfall risks prior to the installation of an additional transformer

Substation	Capacity	Actual Utilisation (%)	Forecast Utilisation (%)																				Mitigation
	MVA	2023	2024		2025		2026		2027		2028		2029		2030		2031		2032		2033		
			PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	PoE 10	PoE 50	
Medina	81	70	76	69	79	72	82	75	84	77	87	81	91	84	94	87	97	91	101	94	105	98	
Mandurah	76	108	112	102	114	104	116	106	118	108	120	110	122	112	124	115	127	117	129	119	132	122	Managed by distribution transfers
Mason Rd	74	69	84	69	85	70	86	71	87	72	88	73	89	75	90	76	91	77	92	78	93	78	
Meadow Springs	86	89	97	90	99	91	101	94	104	97	108	101	112	105	115	108	118	111	121	114	126	119	Additional transformer (estimated in service by FY2026/27)
Murdoch	54	65	73	67	73	68	73	68	74	68	75	69	75	70	76	70	76	71	77	71	78	72	
Myaree	65	68	72	66	72	66	72	66	72	66	74	67	75	69	75	69	75	69	75	69	76	70	
O'Connor	70	74	74	66	75	67	76	68	76	69	77	70	78	71	79	72	80	73	81	74	83	75	
Pinjarra	57	39	42	38	43	39	43	39	44	40	44	41	45	41	45	41	45	41	45	41	45	41	
Rockingham	75	74	86	77	86	77	86	77	87	78	91	82	94	85	95	87	97	88	99	90	102	93	
Riverton	81	81	90	81	91	82	92	83	93	84	95	86	96	87	98	89	99	90	101	92	103	94	
Rivervale	83	59	71	67	73	69	75	70	76	72	78	73	79	75	81	76	82	77	83	78	83	79	
Southern River	85	101	112	109	116	113	120	117	125	122	130	127	136	133	141	138	146	143	151	148	157	154	Additional transformer (estimated in service by FY2026/27)
Waikiki	80	99	101	88	103	90	106	93	110	96	114	101	119	105	122	109	125	112	129	116	135	122	Managed by distribution transfers
Welshpool	90	71	78	72	79	74	80	75	81	75	81	75	80	75	81	75	81	76	82	76	82	77	
Willetton	26	105	108	92	109	93	110	94	111	96	113	98	115	99	116	101	118	102	119	104	121	106	Additional transformer (estimated in service by FY2026/27)

14.3.4 Steady State Voltages

Voltage related performance constraints within the Metro South Region arise during peak demand conditions over the study period, including:

- Low voltages (0.88 pu) and excessive voltage step conditions (-10.23 per cent) by 2025/26 at the Waikiki 132 kV busbar, following the loss of the loss of the Rockingham-Waikiki 132 kV line.

14.3.5 Fault Levels

Due to the heavily meshed 330 kV and 132 kV network at Southern Terminal, fault levels during peak demand conditions are high and can potentially exceed certain plant and earth grid rating if unmanaged. A significant contribution to fault levels comes from the direct 132 kV connection between the Kwinana and Southern terminals, which raises fault levels considerably at both sites. Western Power currently manages this risk by temporarily opening the Southern Terminal to Kwinana 81 circuit during peak demand conditions to reduce fault levels.

14.3.6 Stability

There are no stability-related performance issues in the Metro South Region within the study period.

14.3.7 Reliability

There are no reliability-related performance issues in the Metro South Region within the study period.

14.3.8 Asset

Existing asset performance issues have been identified in the Metro South Region within the study period, including:

- A number of zone and terminal substation transformers in degraded condition require mitigation within the study period, including:
    - Australian Paper Mills - 66/22 kV 32 MVA – T1
    - Byford -132/22 kV 32 MVA - T1
    - Cockburn Cement – 132/22 27 MVA - T1
    - Clarence street - 66/11 kV 27 MVA - T2
    - Collier - 66/11 kV 27 MVA -T1 and T3
    - Canning vale - 132/22 kV 30 MVA - T1 and T2
    - Gosnells - 132/22 kV 31.5 MVA - T2
    - Myaree - 66/22 kV 24 MVA - T1
    - O'Connor - 66/22 kV 27 MVA - T1 and T3
    - Pinjarra - 132/22 kV 15 MVA - T3
    - Rockingham - 132/22 kV 32 MVA - T1 and T3

- Rivervale– 132/32 33.3 MVA - T3

- There are several 22 kV switchboards in the Belmont, Myaree and O'Connor zone substations which are in degraded condition and need to be addressed in the next 10 years.

14.4 Network Augmentation Works

Completed and committed transmission projects in the Metro South are shown in **Table 30**.

Table 30: Completed and Committed Projects – Metro South Region

Project	Scope	Benefits of project	Network driver	By when	Lifecycle Status
Tate Street Substation: Decommission Substation	Offload Tate St zone Substation load to neighbouring zone substations and decommission the 66 kV substation assets.	Address the degraded asset condition of the existing T1 & T3 transformers.	Asset condition	FY2022/23	Completed
Kwinana 132 kV: Overhead line capacity upgrades	Increase the capacity of the following section of 132 kV overhead lines: KM – MED / CC – 2.3km WM- OFE/MSR - 1.1km MSR-OFE/WM - 2.7km MED – KW / CC - 3.3km WM – AFM / RO – 1.7km	Address overhead line capacity shortfalls under high generation conditions in Kwinana area.	Growth – Thermal	FY2023/24	Execution
Kwinana 132 kV: New block load connection	Installation of a new 132 kV circuit from Kwinana to Leath Rd Substation and associated customer connection works.	Facilitate the connection of a new block load customer (28.5 MVA) in Kwinana.	Customer Driven	FY2025/26	Execution
Meadow Springs Substation	Installation of a fourth 132/22 kV 33 MVA transformer and distribution load transfers to offload Mandurah Substation	Address existing substation capacity shortfall and accommodating increase demand in the area	Growth – Thermal	FY2026/27	Initiation

14.5 Network Opportunities

This section highlights possible network opportunities and network solutions in the Metro South Region over the study period. These opportunities will be explored further during the scoping and planning phases of the project lifecycle. If the opportunities are not a technically and economically viable, network solutions will be implemented to address the identified network constraints.

Table 31: Network Opportunities projects – Metro South Region

Location	Scope/Issue	Market Opportunity	By when	Lifecycle Status	Proposed Network Solution
Bibra Lake	Transformer thermal overloads	To reduce demand in the area to eliminate, reduce of defer the need for additional transformer capacity.	FY2027/28	Initiation	Bibra Lake Substation: New Transformer
Willetton	Transformer thermal overloads	Address existing substation capacity shortfall and accommodating increase demand in the area	FY2026/27	Initiation	Willetton Substation: New Transformer
Waikiki	Transformer thermal overloads	To reduce demand in the area to eliminate, reduce of defer the need for additional transformer capacity.	FY2029/30	Initiation	Waikiki Substation: New Transformer
Byford and Southern River	Transformer thermal overloads	Address existing substation capacity shortfall and accommodating increase in demand in the area	FY2026/27	Initiation	New Zone Substation
Mandurah and Meadow Springs	Transformer thermal overloads	Address existing substation capacity shortfall and accommodating increase in demand in the area	FY2026/27	Initiation	Meadow Springs: New Transformer
KW132 IMP 01	Thermal overload of the boundary transfer capacity	Alleviate a number of thermal and voltage capacity constraints.	FY2025/26	Initiation	A second 132 kV Rockingham to Waikiki and 330/132 kV terminal transformer at Kwinana Terminal.
KW330 IMP 01, SF IMP 01 and CT IMP 01 available import capacity	Spare available import capacity exists over a number of import boundaries within the Metro South Region	An opportunity exists to utilise spare available capacity within the KW330 IMP 01, SF IMP 01, CT IMP 01 import boundaries by increasing demand of existing loads or via the connection of new loads	Across the study period	N/A	N/A
KW330 EXP 01 available export capacity	Spare available export capacity exists within the KW330 EXP 01 boundary within Metro South Region	An opportunity exists to utilise spare available capacity within the KW330 EXP 01 export boundaries by connecting new generation.	Across the study period	N/A	N/A

14.6 Emerging Issues and Drivers

The 132 kV transmission network in the Metro South Region is highly meshed, which results in an over-utilised 132 kV network and under-utilised 330 kV network. Western Power is investigating options to de-mesh parts of the 132 kV network to improve efficiency and simplify power flows within and out of the region.

Western Power has received many enquiries regarding the connection of new generators and loads (mainly hydrogen facilities) in the Kwinana load area. Despite several constraints, particularly on the 132 kV networks, the 330 kV network in the Metro South Region is significantly under-utilised, presenting opportunities to support the connection of new loads and large-scale generation.

The progressive retirement of coal generation at Muja and Collie is expected to create changes in the area towards the end of the study period. These retirements are expected to result in a higher reliance on generation from Kwinana in the medium term, while over the longer term, gas-fired generation will also look to be retired.

Significant parts of the Metro South Region have major assets which are reaching the end of their life and need to be addressed. A number of 66 kV networks in this region (e.g., the South Fremantle, Cannington and Kwinana terminals) are anticipated to be either retired or upgraded to 132 kV as they approach their end of service life (within 10 to 20 years).

Western Power is working with industry to better understand how the proliferation of EVs will impact the network in the Metro South Region. Due to the high density of load in this region (particular along the river and in coastal areas), increased EV usage is likely to trigger the need to increase capacity on the transmission system. This may create challenges with service congestion, scarcity of available land, construction of new transmission lines and substations, as well environmental and community approvals.

15. East Perth and CBD Region

15.1 Geography

The East Perth and CBD Region covers the Perth CBD, the City of Subiaco and the City of Vincent. **Figure 60** shows the transmission system in this region.

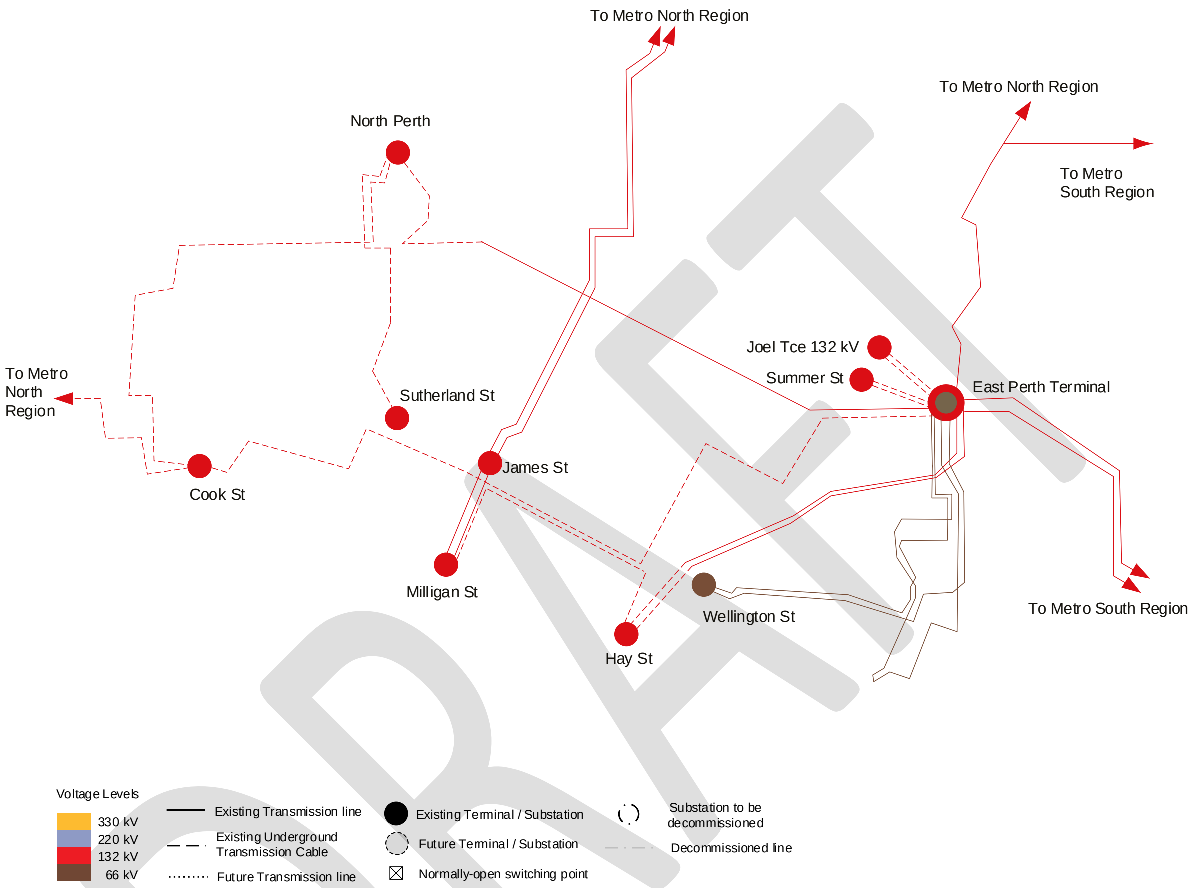

Figure 60: Western Power's East Perth and CBD Region – Network Diagram

The East Perth and CBD Region features one terminal (East Perth) and seven zone substations that are owned and operated by Western Power. The other transmission sites in this region are customer-owned substations.

Terminals

- East Perth Terminal – 132/66 kV

Zone Substation / WP Substations

- Cook Street – 132/11 kV
- Joel Terrace – 132/11 kV[43]
- Hay Street– 132/11 kV
- Milligan Street – 132/11 kV
- North Perth – 132/11 kV
- Wellington Street – 66/11 kV

Customer Substations

- Summer Street (PTA)– 132/11 kV

[43] F has been decommissioned and load transferred to JTE and HAY

15.2 Regional Characteristics

15.2.1 General

The East Perth and CBD Region is characterised by the densely populated areas of West Perth, East Perth, and the CBD. The customers in the region consist of a mixture of commercial, retail, and residential. The region also supports a Public Transport Authority (PTA)-owned substation used to supply rail infrastructure.

Despite several recent major developments in the East Perth and CBD Region, the peak demand levels are forecast to decline over the period. This trend has largely been driven by changing work behaviours that have reduced the demand, particularly in the Perth CBD zone.

15.2.2 Generation

There is no notable generation connected within the East Perth and CBD Region and no generation forecast to be connected within the study period.

15.2.3 Existing Transmission Network Supply

The East Perth and CBD Region is centred on the East Perth Terminal, which delivers power to densely populated areas of West Perth, East Perth and the CBD via seven zone substations and 132 kV and 66 kV sub-transmission networks.

Given the centralised, high-density nature of the load power predominately flows into the Region from neighbouring North and Metro North regions via the Northern and Western terminals to the north and from the Metro South Region via the Southern and Cannington terminals from the south. Although less likely as more generation is connected in the North Region, power transfer can go from the East Perth Terminal to the Northern Terminal under lightly loaded conditions, particularly with minimal generation operating in the North Region.

Supply into the region comes from two 132 kV cables that cross the Swan River via the Graham Farmer Freeway, connecting the Southern Terminal (Metro South Region) and the East Perth Region. There are also 132 kV transmission line/cables between the Western Terminal (Metro North Region) and Cook Street Substation, and a transmission line from Belmont Substation out of Cannington Terminal (Metro South Region) which forms a tee line with a 132 kV circuit connecting East Perth to the Northern Terminal (North Region). For more effective control of power flows into the region, the Belmont end of this tee line predominately operates as normally open. Two 132 kV circuits from the Northern Terminal (North Region) also support a significant portion of CBD substation load at Milligan Street Substation via Mount Lawley.

The transmission lines in this region are generally designed to meet the N-1 capacity criteria, with the exception of supply capacity into Hay Street and Milligan Street which is designed to the Perth CBD N-2 criterion to cater for the increase security of supply reinforcements.

15.2.4 Key Developments in the Region

Over the past 5 to 10 years, the East Perth and CBD Region has undergone transformational changes including Elizabeth Quay, Perth City Link, Riverside and the NextDC data centre. These developments have all been given supply but increases in load for many of these customers is expected to be gradual as construction of the sites develops.
Despite many recent major load developments in the East Perth and CBD Region, peak demand levels are forecast to decline over the period. This trend has largely been driven by flexible and remote working arrangements that have become more common following the COVID-19 pandemic, with the Perth CBD zone experiencing the greatest level of impact.

In late 2018, the State Government announced plans to redevelop the East Perth Power Station and the adjoining land owned by Main Roads. Western Power was asked to investigate costs and an earliest feasible delivery date for the following works to facilitate the redevelopment:

- decommissioning the 66 kV assets East Perth 66 kV Substation
- undergrounding the 132 kV overhead transmission line in the foreshore area of the site.

The above has also triggered works to decommission the 66 kV Forrest Avenue and Wellington Street substations and their 66 kV supplies. Western Power is working towards completing all related works to facilitate redevelopment of the site by 2024.

15.3 Network Performance

This section presents the network performance for the East Perth and CBD Region over the study period.

15.3.1 Thermal Capacity - Boundaries

The following assumptions were made in developing the import and export boundaries:

- Import boundaries consider peak demand and economic generation dispatch conditions.

Import Boundary

Figure 61 shows the network import boundaries in the East Perth and CBD Region. These boundaries are defined using the worst contingency (↯) and the worst overload circuit (*) as shown in **Table 32** .

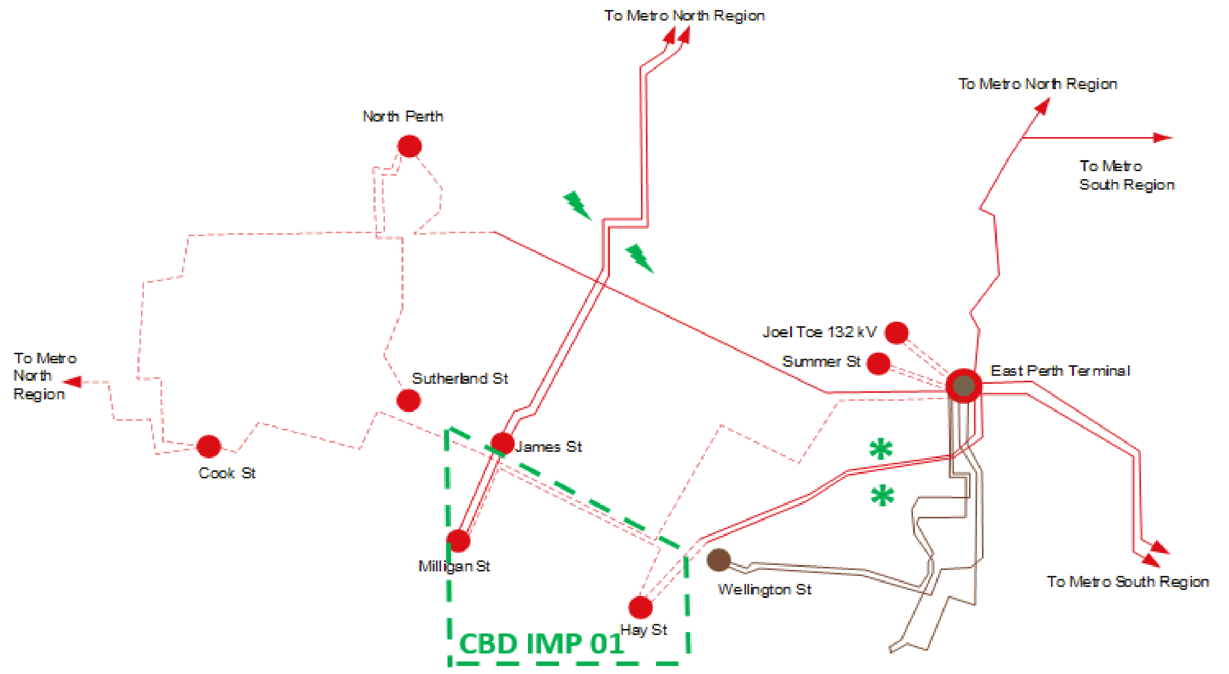

Figure 61: Network import boundaries in the East Perth and CBD Region

Table 32: Thermal import boundary characteristics – East Perth and CBD Region

Characteristics	Import Boundary
	CBDIMP 01
Worst contingency	Mount Lawley to Milligan St 81 and Mount Lawley to Milligan St 82
Contingency type	N-2
Worst circuit/s	East Perth to Hay St 81 and East Perth to Hay St 82

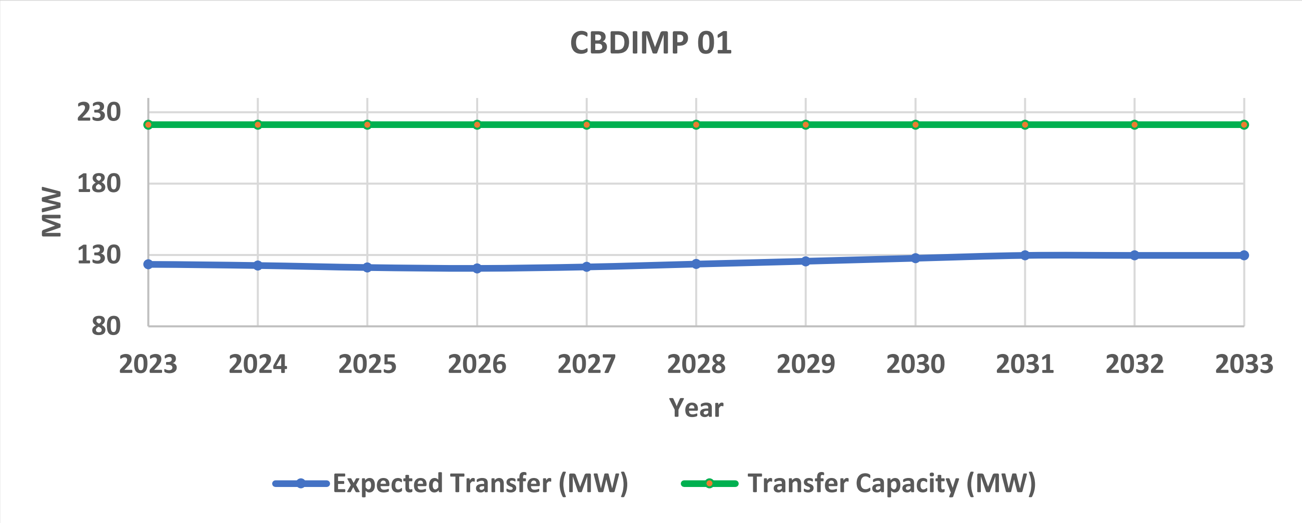

Figure 62: Expected transfer and transfer capacity in CBDIMP 01 boundary – peak demand

As observed in **Figure 62**, there is about 100 MW of available transfer capacity into the CBDIMP 01 boundary over the study period during system peak demand conditions. The transfer capacity into this import boundary is currently limited by the sections of underground cable on the East Perth to Hay 81/82 circuits located between the Wellington Street and Hay Street zone substations that are lower in rating than the overhead sections of the supplies into the Hay Street zone substation.

It should be noted that the peak transfer and transfer capacity indicated in the above figures change as the network evolves or generators/demands behaviour varies.

15.3.2 Thermal Capacity – Transmission Lines

The expected transfers within the East Perth and CBD Region fall within the N-2 transfer capacity over the study period. Thermal Capacity – Zone Substation Transformers. This section shows the existing and forecast peak load utilisation across the period 2022/23 to 2032/33 for all zone substations operated by Western Power within the East Perth and CBD Region.

Table 33: Utilisation legend (for Table 34)

LEGEND	Classification Name	Utilisation %
	Under utilised	below 40%
	Medium utilisation	>40% & 75%
	Highly utilised	>75% & 95%
	Over utilised	above 95%

Table 34: East Perth and CBD Region Zone Substation utilisation heat map

	Capacity	Actual Utilisation (%)	Forecast Utilisation (%)																						Mitigation
Substation	MVA	2022	2023		2024		2025		2026		2027		2028		2029		2030		2031		2032		2033		
			POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	POE 10	POE 50	
Cook St	81	78	78	74	79	74	79	75	79	79	80	7	80	76	80	76	81	76	81	77	81	77	82	78	Additional transformer customer driven (Execution, in service FY2025/26).
Forrest Ave	39	76	76	71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Forrest Ave Substation has been completely decommissioned and load transferred to Hay St and Joel Terrace Substations (Completed).
Hay St	143	50	50	45	50	45	50	45	49	49	48	43	47	42	46	42	46	41	45	41	44	40	44	39	Load transfers from Forrest Ave (Completed)
Joel Terrace	76	71	71	58	75	66	76	68	75	75	72	66	71	63	70	62	71	62	71	63	71	63	70	63	Load transfers from Forrest Ave (Completed)
Milligan St	134	53	53	49	52	48	50	47	49	49	47	43	45	41	44	40	44	38	44	39	44	38	43	37	
North Perth	77	74	74	67	74	67	74	67	74	74	74	67	74	67	74	67	74	67	73	67	73	66	74	67	
Wellington St	29	0	0	0	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	3	3	3	3	Load transfers to Hay, Milligan, and Cook St Substations (Scoping, RIS FY2023/24)

15.3.3 Steady State Voltages

There are no voltage-related performance issues in the East Perth and CBD Region within the study period.

15.3.4 Fault Level

Existing fault level performance constraints were identified in the East Perth and CBD Region within the study period, including:

- A total of eight Mount Lawley Substation 132 kV isolator switches are marginally under fault rated during peak demand conditions. Western Power is replacing two of the isolators with condition issues, while the risk associated with the remaining isolators will be managed by operating the 132 kV bus at the Mount Lawley Substation under a split arrangement to reduce fault levels.

15.3.5 Stability

There are no stability-related performance constraints within the East Perth and CBD Region over the study period.

15.3.6 Reliability

There are no reliability-related performance constraints within the East Perth and CBD Region over the study period.

15.3.7 Asset

Existing asset performance constraints identified in the East Perth and CBD Region within the study period include:

- A number of zone and terminal substation transformers in degraded condition require mitigation within the study period, including:
  - East Perth Terminal – 132/66 KV 100 MVA – T3 and T5
  - Wellington Street – 66/11 KV 20 MVA – T1 and T2
- A large portion of the 66 kV overhead structures and underground cables have less than 10 years remaining service life. In particular, the following underground cables have oil leaks occurring at an increasing rate. These cables present a risk to security of supply, along with posing environmental risks associated with oil leakage.
  - East Perth to Wellington St 71 – 1.8 km
  - East Perth to Wellington St 72 – 2.6 km
  - East Perth to Hay St 81 – 0.6 km
  - East Perth to Hay St 82 – 0.7 km

15.4 Network Augmentation Works

Completed, and committed transmission projects in the East Perth and CBD Region are shown in **Table 35**.

Table 35: Completed and committed projects – East Perth and CBD Region

Project	Scope	Benefits of project	Network driver/s	By when	Lifecycle Status
East Perth Redevelopment	Undergrounding parts of the East Perth to Hay 132 kV circuits to facilitate the East Perth Power Station redevelopment.	Facilitate the redevelopment of the East Perth Power Station site.		FY2022/23 & FY2023/24	Completed
Wellington St Substation: Decommissioning	The 66 kV power transformers and supply lines into Wellington St Substation are to be decommissioned. In addition, the installation of a new 66 MVA Cook St transformer, along with four distribution feeders to the Wellington 11 kV switchboards.	Address multiple degraded 66 kV asset condition issues at Forrest Ave and Wellington St Substations New Cook St transformer and distribution feeders will provide additional operational flexibility to support planned and unplanned outages in the Perth CBD. Installation of a protection inter-trip scheme to facilitate the parallel operation of the new 132 kV Hay-Milligan St cable	Customer Driven /Asset condition.	FY2025/26	Execution

15.5 Network Opportunities

This section highlights possible network opportunities and network solutions in the East Perth and CBD Region over the study period. These opportunities will be explored further during the scoping and planning phases of the project lifecycle. If the opportunities are not a technically and economically viable, network solutions will be implemented to address the identified network constraints.

Table 36: Network Opportunities projects – East Perth and CBD Region

Location	Scope / Issue	Market Opportunity	By when	Lifecycle Status	Proposed Network Solution
CBD IMP 01 available import capacity	Spare available import capacity exists over a number of import boundaries within the East Perth and CBD Region.	An opportunity exists to utilise spare available capacity within the CBD IMP 01 import boundary by increasing demand of existing loads or via the connection of new loads	Across the study period	N/A	N/A

15.6 Emerging Issues and Drivers

Significant network investment within the East Perth and CBD Region has recently been completed and committed to address the risks associated with ageing 66 kV asset infrastructure. Although these works involved a consolidation of major assets, the East Perth and CBD Region has sufficient spare capacity to meet the expected transfers within the region over the study period.

Despite recently completed works involving the refurbishment of the Hay Street and Milligan Street 11 kV switchboards, these assets are expected to require replacement within the next 20 years. Both Hay Street and Milligan Street buildings are more than 40 years old, presenting challenges in maintaining security, compliance with modern standards and reliability of supply while replacing or refurbishing major assets that are nearing their end of asset life.

Over the longer term, demand uncertainty around electrification of vehicles at high levels is likely to present major challenges for the region. Western Power is working with industry to better understand how these changes will impact the network in the region, with a number of new zone substations and supply lines anticipated to meet potentially large increases in demand.

Due to limited access points across the Swan River, service congestion and scarcity of available land, construction of new transmission lines and substations in the region is likely to be difficult. Furthermore, the construction of new transmission lines and zone substations in the area will face challenges in gaining environmental and community approvals, incurring significant expenditure associated with construction and planning. As such, reinforcements in the region inherently incur higher project costs.

16. System Wide Constraints

16.1 Minimum Demand Issues

The SWIS is experiencing an unprecedented transition in the way that electricity is supplied and consumed. The increased integration of renewable generation has led to major changes to both ends of the electricity supply chain. The level of residential DPV connections connected to the SWIS has increased significantly, with more than 1,900 MW of inverter capacity now connected and high growth rates of new DPV connections forecast over the next five years. High levels of DPV capacity and output have resulted in a number of challenges in managing power system security and reliability during periods of low operational demand, particularly during daytime periods where rooftop PV output is high. In response to these growing risks, the State Government announced its Energy Transformation Strategy, details of the can be found in TSP 2022.

In addition to the projects proposed throughout sections 10 to 15, Western Power has developed a number of programs of work to target issues that are experienced throughout the transmission system and are not specific to any one particular Region. The program of works targets voltage, reliability and power quality issues on the transmission network and support managing the low operational demand risks.

Table 37: Completed and committed projects

Project	Scope	Benefits of project	Network driver/s	By when	Lifecycle Status
SWIS UFLS Issues Management	Protection upgrade works across several zone substations to increase the level of remote UFLS telemetry and reverse blocking capability of UFLS loads.	Increase the level of UFLS load shedding availability to maintain the UFLS performance levels and system security risks, particularly during daytime minimum demand periods. Add capability to block UFLS loads that are experiencing reverse powerflows, to avoid exacerbating an UFLS event.	Minimum Demand	FY2023/24	Execution
Transmission UFLS – Temporary solution	The connection of several existing transmission load connections to the UFLS scheme under an emergency pathway via a temporary UFLS solution.	Rapidly increase the level of UFLS load shedding availability to maintain the UFLS performance levels and system security risks, particularly during daytime minimum demand periods. This solution provides limited remote monitoring and control capability and is only intended to be a temporary solution.	Minimum Demand	FY2022/23	Completed

Project	Scope	Benefits of project	Network driver/s	By when	Lifecycle Status
Transmission UFLS – Long-term solution	Upgrading the transmission load customers connected to UFLS with enhanced capability, including remote control (stage selection) and monitoring.	Together with input from customers, the temporary UFLS connections will be upgraded with enhanced functionality that provides redundancy and remote monitoring and control capability. This increased functionality will provide greater flexibility in managing the UFLS load reserves and meeting the UFLS design requirements.	Minimum Demand	FY2024/25	Execution
Dynamic UFLS Management system	Installation of a dynamic UFLS management system	A dynamic UFLS management system is a control system that is designed to automatically manage and optimise the portfolio of available UFLS load shedding reserves in accordance with the current UFLS design requirements.	Minimum Demand	FY2025/26	Initiation
Trial Project: Installation of load banks	Installation of 6 x 5 MVAr load banks at various substations in the metro region.	Provide stable load to support restarting the power system in the event of system wide outages.	Minimum Demand	FY2025/26	Planning

16.2 Network Opportunities

This section highlights possible network opportunities and network solutions on a SWIS wide level over the study period. These opportunities will be explored further during the scoping and planning phases of the project lifecycle. If the opportunities are not a technically and economically viable, network solutions will be implemented to address the identified network constraints

Table 38: Network Opportunities

Project	Scope / Issue	Market Opportunity	By when	Lifecycle Status	Estimated Network Solution Cost ($M)
To be initiated	Minimum Demand	To reduce a number of impacts that arise during periods of low operational demand, an opportunity exists to increase or shift demand patterns during the during the daytime periods (10AM to 3PM) when the rooftop PV output is at high. The opportunity is available throughout the year but is greater in the high-risk spring and autumn periods.	Across the study period	n/a	Yet to be quantified

Appendix A: Our Operating Environment

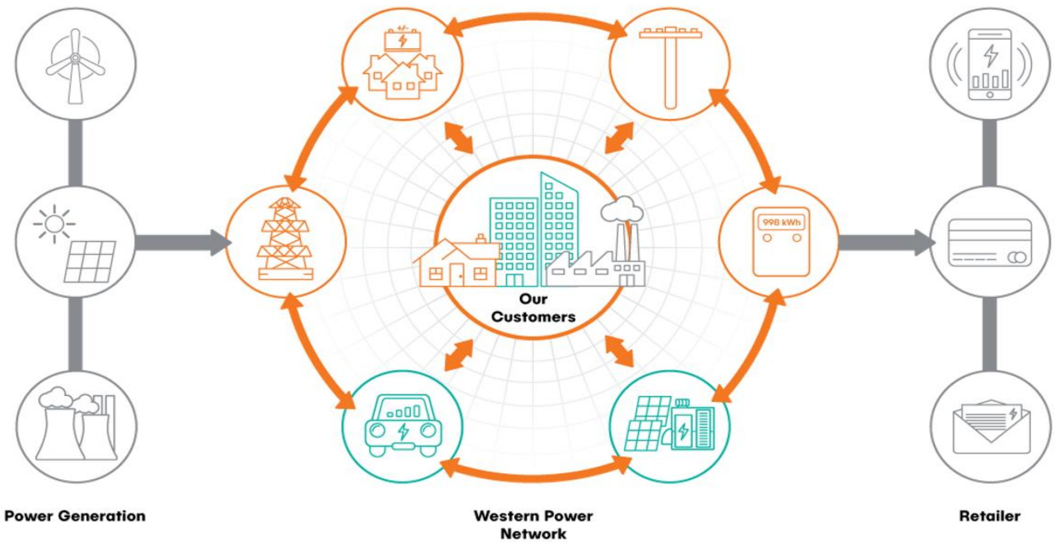

Figure 63: Western Power's role within the Western Australia's electricity market

Western Power is a Western Australian State Government owned corporation responsible for building, maintaining and operating an electricity network. It is licenced under the Electricity Industry Act 2004 (Act) and regulated by the Economic Regulation Authority (ERA), which grants the Electricity Transmission Licence (ETL2) and Electricity Distribution Licence (EDL1) and determines Western Power's revenue, services, policies and incentives via the access arrangement (AA). The network facilitates the Wholesale Electricity Market (WEM) which is operated by the Australian Energy Market Operator (AEMO).

These laws and regulations govern all aspects of our operations, from how funding for works is obtained, to standards of supply and tariff structure. For more information, visit the Energy Policy WA (EPWA) website[44].

44 https://www.wa.gov.au/organisation/energy-policy-wa/regulatory-framework

Appendix B: System Study Modelling Data

This section highlights the key modelling inputs for developing the peak and minimum demand scenarios. Although Western Power and AEMO perform system studies over a wider range of sensitivity scenarios to cover uncertainties in demand and to refine investment timing triggers, system studies presented in the inaugural TSP reflect an efficient and likely generation dispatch for each demand scenario.

B.1 System demand levels

A breakdown of the peak and minimum demand levels used for performing system studies across the study period are shown in **Table 39** and **Table 40**.

Table 39: Breakdown of system demand used for system studies – peak demand

	22/23	23/24	24/25	25/26	26/27	27/28	28/29	29/30	30/31	31/32	32/33
Total Load Demand (MW)	5135	5134	5144	5108	5117	5109	5124	5130	5144	5156	5142
Generator Auxiliary Load (MW)	92	92	84	84	84	61	61	51	51	51	51
HV Customer (MW)	617	627	625	586	584	585	585	585	583	579	571
Imbedded Generator Site Load (MW)	511	510	510	510	510	510	509	507	504	501	475
Normal Substation LV (MW)	3915	3905	3925	3928	3939	3953	3969	3987	4006	4025	4045
Sub-Total Load Demand (excl. Imbedded) (MW)	4624	4624	4634	4598	4607	4599	4615	4623	4640	4655	4667
No. of Synchronous Market Scheduled Units	43	45	44	32	31	36	36	41	41	41	39

Table 40: Breakdown of system demand used for system studies – minimum demand

	22/23	23/24	24/25	25/26	26/27	27/28	28/29	29/30	30/31	31/32	32/33
Total Load Demand (MW)	1223	1119	1001	854	736	600	600	600	600	600	600
Generator Auxiliary Load (MW)	86	86	78	78	78	56	56	56	56	56	56
HV Customer (MW)	425	424	425	393	394	392	390	391	392	392	398
Imbedded Generator Site Load (MW)	481	481	481	482	482	482	476	479	479	477	470
Normal Substation LV (MW)	231	128	17	-99	-218	-330	-270	-314	-330	-298	-419

	22/23	23/24	24/25	25/26	26/27	27/28	28/29	29/30	30/31	31/32	32/33
Sub-Total Load Demand (excl. Imbedded) (MW)	742	638	520	372	254	109	-65	-141	-211	-328	-287
No. of Synchronous Market Scheduled Units	13	15	15	16	16	14	14	13	12	11	10

B.2 Generator dispatch profiles

A breakdown of the generator dispatch profile during peak and minimum demand levels used for performing system studies across the study period are shown in **Table 41** and **Table 42**.

Table 41: Breakdown of generator dispatch profile used for system studies – peak demand

MW Dispatch Level (MW) (To be dispatched at >= Pmin value)	22/23	23/24	24/25	25/26	26/27	27/28	28/29	29/30	30/31	31/32	32/33
Total Generation (MW)	**5291**	**5352**	**5400**	**5458**	**5484**	**5493**	**5510**	**5560**	**5577**	**5592**	**5416**
Total Synch. Market Scheduled demand (MW)	4290	4359	4161	3816	3793	3641	3658	3433	3438	3434	3387
No. of Synchronous Market Scheduled Units	43	45	44	32	31	36	36	41	41	41	39
GEN KBA GT	35	35	35	35	35	35	35	35	35	35	35
Gen_APJ_GT1 & GT2	284	284	284	284	284	274	276	282	279	274	275
Gen_AWG_GT1 & GT2	380	380	380	380	380	380	380	380	380	380	380
Gen_BWP_G1 & G2	434	434	434	434	434	434	434	434	434	434	434
Gen_CKB_GT1 & SG1	239	240	240	240	240	240	240	240	240	240	240
Gen_CPS_G1	326	327	329	316	321	0	0	0	0	0	0
Gen_GNN_GT11 & GT12	336	336	336	336	336	336	336	336	336	336	336
Gen_KMK_GT1	34	34	34	34	34	34	34	34	34	34	34
Gen_KMP_GT1 & GT2	302	302	302	302	302	302	302	302	302	302	302
Gen_KND_GT1 & GT2	120	120	120	120	120	120	120	120	120	120	120
Gen_KNS_GT2	35	35	35	35	35	35	35	35	35	35	35
Gen_MDP_G1 & G2	80	80	80	0	0	0	0	80	80	80	80
Gen_MPS_G6, G7, G8	600	600	400	400	400	400	400	0	0	0	0
Gen_NGK_GT3 & SG3	326	324	324	324	324	324	324	324	324	325	325
Gen_PJR_GT1 to GT7	194	194	194	58	29	170	185	194	194	194	194
Gen_PJR_GT9, GT10 & GT11	331	331	331	331	331	331	331	331	331	331	331

MW Dispatch Level (MW) (To be dispatched at >= Pmin value)	22/23	23/24	24/25	25/26	26/27	27/28	28/29	29/30	30/31	31/32	32/33
Gen_PRK_GT1, GT2 & GT3	114	114	114	38	38	76	76	114	114	114	76
KW_HEGT_G2 & G3	80	80	80	80	80	80	80	80	80	80	80
KW_WTE	0	37	37	37	38	38	38	38	46	46	46
ERRRF_WTE	0	32	32	32	32	32	32	34	34	34	34
Distribution Machines	40	40	40	0	0	0	0	40	40	40	30
Renewable Generation (MW)											
AWF - Albany Wind Farm	9	9	9	9	9	9	9	9	9	9	9
BGA - Badgingarra Wind Farm	54	54	54	54	54	54	54	54	54	54	54
CGW - Collgar Wind Farm	131	102	102	82	82	82	82	122	122	122	82
CNS - Cunderdin Solar Farm	0	0	11	11	11	11	11	11	11	23	11
EMD - Emu Downs	17	33	33	33	33	33	33	33	33	33	33
FRW - Flat Rocks Wind Farm	0	30	30	30	30	30	30	30	30	37	30
GRS - Greenough River Solar Farm	19	19	19	19	19	19	19	19	19	19	19
GWF - Grasmere	5	5	5	5	5	5	5	5	5	5	5
KDW – Kondinin Wind Farm	0	0	0	0	48	48	48	48	48	48	48
KRW – King Rocks Wind Farm	0	0	0	32	32	32	32	32	32	32	32
MBA - Mumbida Wind Farm	36	30	24	24	24	24	24	24	36	36	24
MRS - Merredin Solar Farm	33	22	11	11	11	11	11	22	22	22	11
WDI - Waddi Wind Farm	0	0	0	22	42	42	42	42	42	42	42
WDW - Warradarge Wind Farm	108	90	90	99	99	99	99	123	123	123	99
WWF - Walkaway Wind Farm	35	35	35	35	35	35	35	35	35	35	35
YDW - Yandin Wind Farm	126	105	105	84	84	84	84	105	105	105	84
Distribution PPGs	27	27	27	27	27	27	27	27	27	27	27
Battery Storage (MW)											
AWB - Alinta Wagerup BESS	0	0	48	48	48	48	48	48	48	48	48
COB – Synergy Collie BESS	0	0	0	387	387	387	387	486	486	486	486
KWB - Kwinana BESS	0	48	48	48	48	48	48	48	48	48	48
NEO - Neoen Collie BESS	0	0	198	159	159	159	159	196	196	196	196

Table 42: Breakdown of generator dispatch profile used for system studies – minimum demand

MW Dispatch Level (MW) (To be dispatched at >= Pmin value)	22/23	23/24	24/25	25/26	26/27	27/28	28/29	29/30	30/31	31/32	32/33
Total Generation (MW)	1258	1229	1129	1497	1387	1253	1136	1034	959	844	747
Total Synch. Market Scheduled demand (MW)	836	839	844	1240	1130	894	884	782	707	592	564
No. of Synchronous Market Scheduled Units	13	15	15	16	16	14	14	13	12	11	10
GEN KBA GT	20	20	20	20	20	20	20	20	20	20	20
Gen_APJ_GT1 & GT2	90	90	90	240	240	262	262	262	142	142	142
Gen_BWP_G1 & G2	323	274	287	370	240	242	172	110	225	110	110
Gen_KMK_GT1	14	14	14	14	14	14	14	14	14	14	14
Gen_KNS_GT2	19	19	19	19	19	19	19	19	19	19	19
Gen_MPS_G6, G7, G8	200	170	190	180	200	0	0	0	0	0	0
Gen_PJR_GT1 to GT7	15	28	28	48	48	28	48	28	28	28	0
Gen_PJR_GT9, GT10 & GT11	75	75	75	200	200	160	200	180	110	110	110
KW_HEGT_G2 & G3	80	80	80	80	80	80	80	80	80	80	80
ERRRF_WTE	0	32	32	32	32	32	32	32	32	32	32
KW_WTE	0	37	37	37	37	37	37	37	37	37	37
Renewable Generation (MW)											
AWF - Albany Wind Farm	5	5	5	5	5	5	5	5	5	5	5
BGA - Badgingarra Wind Farm	6	6	6	6	6	6	14	14	14	14	14
CGW - Collgar Wind Farm	11	11	11	20	20	20	20	20	20	20	20
CNS - Cunderdin Solar Farm	0	0	99	55	55	91	91	91	91	91	91
EMD - Emu Downs	19	19	19	19	19	19	19	19	19	19	19
FRW - Flat Rocks Wind Farm	0	4	4	7	7	7	7	7	7	7	7
GRS - Greenough River Solar Farm	0	0	0	0	0	0	0	0	0	0	0
GWF - Grasmere	1	1	1	1	1	1	1	1	1	1	1
KDW – Kondinin Wind Farm	0	0	0	0	0	0	0	0	0	0	0
KRW – King Rocks Wind Farm	0	0	0	0	0	0	0	0	0	0	0
MBA - Mumbida Wind Farm	3	3	3	3	3	3	3	3	3	3	3
MRS - Merredin Solar Farm	49	49	49	49	49	49	49	49	49	49	49
WDI - Waddi Wind Farm	0	0	0	0	0	0	0	0	0	0	0
WDW - Warradarge Wind Farm	9	9	18	74	74	137	24	24	24	24	24

MW Dispatch Level (MW) (To be dispatched at >= Pmin value)	22/23	23/24	24/25	25/26	26/27	27/28	28/29	29/30	30/31	31/32	32/33
WWF - Walkaway Wind Farm	4	4	4	4	4	4	4	4	4	4	4
YDW - Yandin Wind Farm	10	10	21	21	21	21	21	21	21	21	21
Distribution PPGs	14	14	14	14	14	14	14	14	14	14	14

B.3 Network Configuration Assumptions

A list of the network configuration during peak and minimum demand levels used for performing system studies across the study period are shown in **Table 43**.

Table 43: Network Configuration Assumptions

	Peak Demand	Minimum Demand
Northern Terminal to Muja 330 kV (Muja end)	Close	Open
Northern Terminal 132 kV busbar status	Open/Split Bus	Close/Parallel Bus
Northern Terminal T2 status	In Service	In Service
Kwinana Bus Tie Transformer 1	Out of Service	Out of Service
Mount Lawley 132 kV busbar status	Open	Close
Belmont – Northern Terminal/ East Perth 132 kV line (Belmont end)	Open	Open
Wagin - Narrogin South/Narrogin (Narrogin South/Narrogin ends)	Open	Open
Cunderdin – Kelleberin 66 kV (Kelleberin end)	Open	Open
Kemerton-Busselton-Picton/Pinjarra 132 kV line (Picton end)	Open	Open
South Fremantle – Southern Terminal 132 kV & Southern Terminal- Kwinana 132 kV (at Southern Terminal end)	Close / Without Bypassing Southern Terminal	Close / Without Bypassing Southern Terminal
Southern Terminal – Kwinana 132 kV line	Close	Close
Hay – Milligan 132 kV cable (at Milligan end)	Open	Open

Appendix C: Estimated Maximum/Minimum Short Circuit Levels

Per the requirements under clause 5.5.1 b) of the Technical Rules, this appendix provides the existing and five-year forecast maximum and minimum short circuit levels at each of the Western Power network's major transmission nodes. This information will allow existing and future users to procure, design and operate their equipment within the expected maximum and minimum short circuit (or fault) levels at their connection point.

Short circuit level calculations were determined in accordance with the following:

- The IEC 60909 method was used for the calculations; this is the source standards upon which the current Australian and New Zealand standards (AS/NZS 3851) is based.
- For maximum fault levels, the C factor (as defined by IEC 60909) is set at 1.1 pu at the fault bus. For minimum fault levels, the C factor is set at 1.0 pu.
- Zero fault impedance is assumed.
- For maximum fault levels, all generation machines and step-up transformers are turned on.
- All lines are in service.

The expected fault current shown is I_{KSS}.[45]

[45] AC component of the initial symmetrical short circuit current which occurs directly after the initiation of the fault (RMS value).

Table 44: Maximum fault levels

Current Levels (0 years)				Future Levels (5 years)	
Substation	Voltage (kV)	Fault Level 3-phase (kA)	Fault Level 1-phase (kA)	Fault Level 3-phase (kA)	Fault Level 1-phase (kA)
East Region					
BDE - Bandee	66	1.9	1.6	1.9	1.6
BKF - Black Flag	132	3.1	3.2	3.1	3.2
BLD - Boulder	132	6.2	7.3	6.2	7.3
BNY - Bounty	132	0.7	0.9	0.9	1.1
CAR - Carrabin	66	1.3	1.0	1.3	1.0
CGT - Collgar Terminal	220	3.5	4.6	3.9	4.7
CGW - Collgar Wind Farm	220	3.5	4.6	3.9	4.7
CUN - Cunderin	66	1.1	0.8	1.2	0.8
JAN-Jan	132	2.1	2.2	2.2	2.2
KDN - Kondinin	220	3.2	2.9	3.9	3.8
KDN - Kondinin	132	1.5	1.7	1.5	1.7
KEL - Kellerberrin	66	1.2	0.9	1.2	0.9
LEF-Lefroy	132	2.4	2.6	2.4	2.6
MDP - Merredin Power Station	132	6.3	8.5	6.9	8.8
MER - Merredin	66	3.9	5.3	4.1	5.4
MER - Merredin	132	5.3	6.4	5.9	6.6
MRS - Merredin Solar Farm	220	3.8	5.0	4.3	5.2
MRT - Merredin Terminal	132	6.3	8.5	4.3	5.3
MRT - Merredin Terminal	220	3.8	5.0	3.8	5.0
MW-Mundering Weir	66	3.7	2.6	3.9	2.6
NOR - Northam	132	5.3	5.4	5.7	5.8
NOR - Northam	66	4.7	4.6	4.9	4.7
PCY - Piccadilly St	132	6.1	7.4	6.2	7.4
PKS - Parkeston Substation	132	5.9	6.8	6.0	6.8
SVY - Sawyers Valley 132kV	132	7.9	6.9	8.2	7.0
SX - Southern Cross	66	0.6	0.4	0.6	0.4
WKT - West Kalgoorlie	132	6.3	8.1	6.4	8.2
WKT - West Kalgoorlie	220	2.6	3.3	3.4	4.2
WMK - Western Mining Kambalda	132	2.8	3.1	3.0	3.3
WMS - Western Mining Smelter	132	4.3	4.8	5.2	5.6
WUN - Wundowie	66	2.9	2.1	3.0	2.1
YER - Yerbillon	66	1.2	0.9	1.2	0.9
YLN - Yilgarn	220	2.8	2.7	2.9	2.7

Current Levels (0 years)				Future Levels (5 years)	
Substation	Voltage (kV)	Fault Level 3-phase (kA)	Fault Level 1-phase (kA)	Fault Level 3-phase (kA)	Fault Level 1-phase (kA)
East Perth & CBD					
CK - Cook Street	132	22.7	22.5	23.4	22.7
EP - East Perth	66	5.6	7.0	5.9	7.1
EP - East Perth	132	21.4	20.7	25.4	26.0
F - Forrest Ave	66	5.2	5.6		
HAY - Hay Street	132	21.4	20.7	22.0	20.9
JTE - Joel Terrace 132kV	132	24.2	24.5	25.0	25.0
MIL - Milligan Street	132	19.1	19.2	19.7	19.4
NP - North Perth	132	21.0	20.1	21.6	20.3
SUM - Summers Street	132	24.4	25.1	25.1	25.4
W - Wellington Street	66	5.4	6.0	5.4	6.0
Metro North					
A - Arkana	132	19.7	19.7	19.6	19.6
BCH - Beechboro	132	19.5	18.6	20.1	18.7
BCT - Balcatta	132	18.9	17.8	19.5	18.0
CTE - Cottesloe 132kV	132	18.2	15.5	18.7	15.7
D-Darlington	132	13.6	12.7	13.5	12.7
FFD - Forrestfield	132	13.3	13.1	13.8	13.3
GLT - Guildford Terminal	132	22.9	24.8	23.8	25.1
H - Hadfields	132	16.5	15.4	16.4	15.4
HZM - Hazelmere	132	22.3	23.6	23.1	23.9
K - Kalamunda	132	11.4	10.8	11.3	10.8
LDE - Landsdale	132	17.9	17.3	18.4	17.5
MA - Manning Street	132	17.8	17.1	18.4	17.3
MDY - Munday	132	13.3	13.0	13.7	13.2
MJ - Midland Junction	132	21.5	23.0	22.3	23.3
MLA - Mount Lawley	132	20.9	20.8	21.6	21.0
MO - Morley	132	17.1	17.9	17.7	18.0
N - Nedlands	66	11.0	11.3	11.0	11.3
NB - North Beach	132	19.4	19.0	20.0	19.1
OP - Osborne Park	132	19.5	19.6	20.1	19.8
SPK - Shenton Park	132	20.4	19.8	21.0	19.9
WD - Wembley Downs	66	9.6	8.0	22.3	21.8
WT - Western Terminal	66	13.2	16.6	22.3	21.8
Y - Yokine	132	19.2	18.4	19.3	18.6
Metro South					
AFM- Australian Fused Materials	132	18.9	17.7	19.6	18.0
AKW - ALCOA Kwinana	132	25.2	27.8	26.1	28.7
AMT - Amherst	132	19.6	16.8	20.1	16.9
APM - Australian Paper Mills	66	9.3	8.0	9.6	8.1
BEC - Beckenham	132	26.6	28.5	27.4	28.8

Current Levels (0 years)				Future Levels (5 years)	
Substation	Voltage (kV)	Fault Level 3-phase (kA)	Fault Level 1-phase (kA)	Fault Level 3-phase (kA)	Fault Level 1-phase (kA)
BEL - Belmont	132	18.5	18.0	19.1	18.1
BHK - Broken Hill Kwinana	66	3.9	3.5	4.0	3.5
BIB - Bibra Lake	132	21.1	18.2	21.6	18.4
BP - British Petroleum	66	4.6	4.6	4.7	4.6
BPR - B.P. Refinery	132	21.5	22.2	22.4	22.9
BTY - Bentley	132	19.2	16.7	19.8	16.9
BYF - Byford	132	13.2	11.5	13.5	11.6
CBP-CSBP	132	20.8	21.2	21.7	21.9
CC - Cockburn Cement	132	23.7	21.1	24.3	21.2
CCL - Cockburn Cement Ltd	132	23.6	21.0	24.1	21.1
CKB - Cockburn Power	132	29.8	32.5	30.4	32.8
CL - Clarence St	66	8.8	6.9	9.1	7.0
COL - Collier	66	8.9	7.0	9.2	7.1
CT - Cannington Terminal	66	14.5	17.5	15.1	17.6
CT - Cannington Terminal	132	11.5	11.7	11.9	11.8
CVE - Canning Vale	132	18.7	18.3	19.2	18.5
E - Edmund Street	66	10.9	10.5	10.8	10.5
G - Gosnells	132	21.9	21.2	22.0	21.3
GNI - Glen Iris	132	26.5	28.2	27.0	28.0
KDL - Kewdale	132	18.0	16.7	18.5	16.7
KDP - Kwinana Desalination Plant	132	24.9	27.0	23.5	25.4
KMK - Kerr McGee Kwinana	132	24.0	26.9	25.1	28.0
KND-Kwinana Donaldson Road	132	23.3	26.1	24.3	27.1
KNL - Kenwick Link	132	25.2	25.9	26.0	26.1
KNL - Kenwick Link	330	16.2	15.5	16.6	15.4
KPP - Kwinana Power Partnership	132	22.0	23.1	23.0	23.9
KW - Kwinana	66	4.0	3.7	5.8	6.9
KW - Kwinana	132	24.1	26.1	30.4	32.8
KW - Kwinana	330	20.0	20.8	26.3	29.1
LTH - Leath Road_Kwinana Waste Energy	132	19.5	19.6	24.3	26.0
MDN - Maddington	132	22.2	20.3	22.9	20.5
MED - Medina	132	22.1	19.9	22.6	20.0
MH - Mandurah	132	10.5	10.2	10.8	10.3
MSR - Mason Road	132	24.0	26.9	25.1	28.0
MUR - Murdoch	132	23.1	21.7	23.8	21.9
MYR - Myaree	66	8.7	7.4	9.0	7.5
OC - OConnor	66	9.9	9.7	10.2	9.8
OFE-Office Road	132	20.5	20.2	21.3	20.6
PLD - Parklands	132	11.1	11.0	11.1	11.1
PNJ - Pinjarra	132	14.0	12.8	14.5	12.9
RO - Rockingham	132	18.9	18.1	19.4	18.3

Current Levels (0 years)				Future Levels (5 years)	
Substation	Voltage (kV)	Fault Level 3-phase (kA)	Fault Level 1-phase (kA)	Fault Level 3-phase (kA)	Fault Level 1-phase (kA)
RTN - Riverton	132	19.5	17.2	20.1	17.4
RVE - Rivervale	132	17.4	16.2	18.0	16.4
SF - South Fremantle	132	26.4	24.0	27.1	24.2
SF - South Fremantle	66	13.9	17.0	14.3	17.2
SNR - Southern River	132	20.2	18.6	20.8	18.8
ST - Southern Terminal	132	30.2	33.6	31.1	33.9
ST - Southern Terminal	330	21.1	22.0	21.8	22.1
TLA - Tianqi Lithium Australia	132	18.5	18.7	22.8	24.0
TPP- Tiwest Pigment Plant	132	24.0	26.9	25.1	28.0
VP - Victoria Pak	66	11.5	11.5	11.8	11.6
WAI - Waikiki	132	14.8	13.4	15.2	13.5
WE - Welshpool	132	20.7	20.6	21.3	20.7
WLN - Willetton	132	19.3	18.8	19.9	19.0
WM - Western Mining	132	20.6	20.1	21.3	20.5
North					
CKN - Clarkson	132	15.3	13.5	15.7	13.5
CPN - Chapman	132	2.7	3.3	2.8	3.3
CTB - Cataby	132	6.6	6.4	6.8	6.5
EDG - Edgewater	132	19.4	18.9	19.9	19.1
EMD - Emu Downs	132	3.8	3.6	5.3	4.8
ENB - Eneabba	132	6.4	5.9	6.6	6.1
ENT - Eneabba Terminal	330	3.9	4.5	4.1	4.6
GGV - Golden Grove	132	1.3	0.9	1.3	0.9
GNN - Newgen Neerabup	330	13.5	13.3	13.9	13.4
GRS - Greenough River Solar Farm	132	4.2	4.5	4.2	4.5
GTN - Geraldton	132	2.9	3.6	3.0	3.6
HBK - Henley Brook	132	12.9	10.5	13.2	10.6
JDP - Joondalup	132	18.9	18.0	19.4	18.2
KMC- Kerr McGee Cataby	132	6.6	6.4	6.8	6.5
KMM - Kerr McGee Muchea	132	14.3	10.6	14.2	10.6
KRA - Karara Mine	330	2.2	3.0	2.2	3.0
MBA - Mumbida Wind Farm	132	4.7	4.9	3.9	4.0
MGA - Mungarra	132	4.2	4.5	4.2	4.5
MOR - Moora	132	2.8	1.8	2.8	1.8
MUC - Muchea	132	17.9	14.1	18.3	14.2
MUL - Mullaloo	132	19.3	19.0	19.9	19.1
NBT - Neerabup Terminal	132	21.5	21.6	22.2	21.6
NBT - Neerabup Terminal	330	21.6	21.5	14.3	13.8
NOW - Nowergup	132	15.1	13.3	15.4	13.4
NT - Northern Terminal	132	28.6	33.3	29.6	33.7
NT - Northern Terminal	330	17.8	18.1	18.3	18.0

Current Levels (0 years)				Future Levels (5 years)	
Substation	Voltage (kV)	Fault Level 3-phase (kA)	Fault Level 1-phase (kA)	Fault Level 3-phase (kA)	Fault Level 1-phase (kA)
PBY - Padbury	132	17.7	16.3	18.2	16.5
PJR - Pinjar Power Station	132	29.8	32.1	30.5	32.4
RAN - Rangeway	132	2.8	3.4	3.4	4.1
RGN - Regans	132	6.0	5.8	6.1	5.8
TS - Three Springs	132	7.5	7.6	7.7	7.7
TST - Three Springs Terminal	132	7.5	8.0	7.7	8.1
TST - Three Springs Terminal	330	3.4	4.5	3.4	4.5
WDW - Warradarge Wind Farm	330	3.6	4.3	3.8	4.4
WGA - Wangara	132	17.2	16.2	17.7	16.4
WNO - Wanneroo	132	20.3	19.8	20.9	20.0
WWF - Walkaway Wind Farm	132	3.6	4.1	3.7	4.1
YDT - Yandin Terminal	330	5.4	5.6	5.6	5.7
YDW - Yandin Wind Farm	330	4.9	5.2	5.1	5.2
YP - Yanchep	132	15.1	13.2	15.4	13.3
South					
ALB - Albany	132	1.6	1.9	1.8	1.9
APJ - ALCOA Pinjarra	330	14.8	12.8	14.8	14.9
APJ - ALCOA Pinjarra	132	14.8	14.8	15.2	15.0
BDP-Binningup Desalination Plant	132	11.6	9.3	11.6	9.3
BGM - Boddington Gold Mine	132	9.9	9.9	10.7	10.2
BLW - Bluewaters Terminal	330	20.5	19.7	21.2	20.4
BNP - Beenup	132	1.2	1.2	1.3	1.3
BOD - Boddington	132	9.9	9.9	10.7	10.2
BSI- Barrack Silicon Smelter	132	15.1	13.4	18.0	15.1
BSN - Busselton	66	4.2	5.2	4.5	5.3
BSN - Busselton	132	2.6	3.0	2.7	3.1
BTN - Bridgetown	132	4.5	4.7	4.7	4.8
BUH - Bunbury Harbour	132	9.6	9.6	10.3	9.9
BWP - Bluewaters Power Station	330	20.5	19.7	21.2	20.4
CAP - Capel	66	5.1	5.1	5.4	5.2
CO - Collie	66	2.1	1.7	2.2	1.7
CPS - Collie Power Station Terminal	330	18.8	18.1	19.9	20.0
KAT - Katanning	66	1.5	1.7	1.6	1.7
KEM - Kemerton	132	20.7	22.1	26.6	28.1
KEM - Kemerton	330	21.0	19.4	21.2	19.7
KMP - Kemerton Power	330	19.5	17.7	20.3	18.6
KOJ - Kojonup	66	2.7	2.9	3.8	4.1
KOJ - Kojonup	132.0	3.8	4.2	4.3	4.4
LWT - Landwehr Terminal	330	16.2	15.2	16.9	16.3
MBR - Mount Barker	132	1.6	1.7	1.8	1.8
MJP - Manjimup	132	3.0	3.1	3.2	3.1

Current Levels (0 years)				Future Levels (5 years)	
Substation	Voltage (kV)	Fault Level 3-phase (kA)	Fault Level 1-phase (kA)	Fault Level 3-phase (kA)	Fault Level 1-phase (kA)
MR - Margaret River	66	1.6	1.8	1.7	1.9
MRR - Marriott Road	132	17.1	16.4	20.7	18.9
MU - Muja	66	3.7	3.8	3.9	3.9
MU - Muja	132	17.7	19.8	18.5	19.8
MU - Muja	220	8.4	9.3	8.9	9.2
MU - Muja	330	21.5	20.7	19.9	18.8
NGN - Narrogin	66	1.2	1.6	1.2	1.6
NGS - Narrogin South	220	3.7	3.0	3.7	3.0
OLY - Oakley	330	16.8	14.7	17.5	14.8
PIC - Picton	66	9.7	12.1	10.3	12.4
PIC - Picton	132	11.3	11.7	12.3	12.2
SHO - Shotts	330	20.3	19.6	21.3	21.2
WAG - Wagin	66	1.2	1.0	1.3	1.1
WAPL- Worsely Alumina Pty Ltd	66	4.0	4.5	4.0	4.5
WAPL- Worsely Alumina Pty Ltd	132	14.5	16.7	15.0	16.8
WCG- Worsely Co Generation	132	14.6	16.7	15.1	16.9
WCL -Western Colleries Limited	132	13.6	11.9	14.3	12.0
WGP - Wagerup	132	8.6	6.9	8.8	7.0
WLT - Wells Terminal	132	11.3	12.2	12.2	12.5
WLT - Wells Terminal	330	7.1	6.7	7.5	6.8
WOR - Worsley	132	14.6	16.7	15.1	16.9
WSD - Westralian Sands	66	4.8	4.1	5.1	4.2

Table 45: Minimum fault levels

		Current Levels (0 years)		Future Levels (5 years)	
Substation	Voltage (kV)	Fault level 3-phase (kA)	Fault level 1-phase (kA)	Fault level 3-phase (kA)	Fault level 1-phase (kA)
East Region					
BDE - Bandee	66	1.4	1.2	1.4	1.2
BKF - Black Flag	132	1.2	1.4	2.0	1.8
BLD - Boulder	132	2.7	3.3	3.2	4.1
BNY - Bounty	132	0.6	0.4	0.6	0.4
CAR - Carrabin	66	1.0	0.8	1.0	0.8
CGT - Collgar Terminal	220	0.6	0.6	1.9	0.6
CGW - Collgar Wind Farm	220	1.9	2.2	1.9	2.2
CUN - Cunderdin	66	0.9	0.7	0.9	0.7
JAN-Jan	132	1.7	1.8	1.7	1.8
KDN - Kondinin	220	1.3	1.3	1.3	1.3
KDN - Kondinin	132	0.8	0.9	0.8	0.9
KEL - Kellerberrin	66	0.9	0.7	0.9	0.7
MDP - Merredin Power Station	132	3.0	4.0	2.9	4.0
MER - Merredin	66	1.9	2.5	1.9	2.5
MER - Merredin	132	2.7	3.4	2.7	3.3

Substation	Voltage (kV)	Current Levels (0 years) Fault level 3-phase (kA)	Current Levels (0 years) Fault level 1-phase (kA)	Future Levels (5 years) Fault level 3-phase (kA)	Future Levels (5 years) Fault level 1-phase (kA)
MRS - Merredin Solar Farm	220	1.0	1.4	1.9	2.6
MRT - Merredin Terminal	132	2.3	3.2	2.3	3.2
MRT - Merredin Terminal	220	1.0	1.4	1.0	1.4
MW- Mundaring Weir	66	0.8	0.6	0.8	0.6
NOR - Northam	132	2.7	2.6	2.7	2.5
NOR - Northam	66	2.3	1.6	2.3	1.6
PCY - Piccadilly St	132	2.1	2.6	2.7	3.3
PKS - Parkeston	132	0.6	0.5	2.1	2.6
SVY - Sawyers Valley 132 kV	132	0.5	0.4	1.3	1.0
SX - Southern Cross	66	1.1	0.8	0.5	0.4
WKT - West Kalgoorlie	132	2.1	2.7	2.1	2.7
WKT - West Kalgoorlie	220	0.6	0.5	0.6	0.5
WMK - Western Mining Kambalda	132	0.6	0.7	1.5	1.4
WMS - Western Mining Smelter	132	0.6	0.7	0.6	0.7
WUN - Wundowie	66	0.9	0.7	1.1	0.8
YER - Yerbillon	66	0.7	0.6	0.9	0.7
YLN - Yilgarn	220	2.0	1.8	0.7	0.7
East Perth and CBD Region					
CK - Cook Street	132	11.1	10.5	10.0	9.7
EP - East Perth	66	4.7	5.9	4.6	5.7
EP - East Perth	132	11.9	13.1	10.9	12.0
HAY - Hay Street	132	11.7	11.4	10.5	10.4
JTE - Joel Terrace	132	13.8	14.8	12.2	13.3
MIL - Milligan Street	132	10.3	10.3	9.1	9.3
NP - North Perth	132	12.5	13.1	9.9	8.8
SUM - Summers Street	132	13.7	14.9	12.1	13.3
W - Wellington Street	66	4.5	5.1	4.4	5.0
Metro North Region					
A - Arkana	132	7.3	6.2	6.7	5.8
BCH - Beechboro	132	6.2	5.3	5.8	5.0
BCT - Balcatta	132	8.3	7.7	7.4	7.1
CTE - Cottesloe	132	6.9	5.5	6.5	5.3
D-Darlington	132	4.9	4.7	4.7	4.5
FFD - Forrestfield	132	4.2	4.1	4.0	3.9
GLT - Guildford Terminal	132	1.4	0.8	1.4	0.8
H - Hadfields	132	7.5	6.5	6.8	6.1
HZM - Hazelmere	132	6.6	5.2	6.1	4.9
K - Kalamunda	132	5.1	3.9	4.8	3.8
MA - Manning Street	132	8.0	7.0	7.2	6.6
MCE - Medical Centre	66	6.2	4.8	6.0	4.7
MDY - Munday	132	4.2	3.3	4.0	3.2
MJ - Midland Junction	132	3.8	3.4	10.5	11.2
MLA - Mount Lawley	132	12.0	13.7	10.4	12.0
MLG - Malaga	132	15.9	19.8	13.3	16.6
MO - Morley	132	6.7	5.3	6.2	5.0
MVE – Maida Vale	132	4.2	3.3	4.0	3.2

Substation	Voltage (kV)	Current Levels (0 years)		Future Levels (5 years)	
		Fault level 3-phase (kA)	Fault level 1-phase (kA)	Fault level 3-phase (kA)	Fault level 1-phase (kA)
N - Nedlands	66	6.8	6.3	6.6	6.2
NB - North Beach	132	9.6	9.1	8.5	8.3
OP - Osborne Park	132	10.0	9.6	8.9	8.7
SPK - Shenton Park	132	6.5	4.6	6.0	4.4
WD - Wembley Downs	66	3.8	2.5	3.7	2.5
WT - Western Terminal	66	3.3	2.1	7.6	2.0
Y - Yokine	132	8.0	7.1	7.3	6.6
Metro South Region					
AFM- Australian Fused Materials	132	11.6	11.8	10.6	11.0
AKW - ALCOA Kwinana	132	14.6	16.9	13.0	15.1
AMT - Amherst	132	6.1	5.0	5.7	4.7
APM - Australian Paper Mills	66	4.0	2.8	3.9	2.8
BEC - Beckenham	132	14.7	16.5	6.2	15.0
BEL - Belmont	132	8.1	6.7	13.3	6.5
BHK - Broken Hill Kwinana	66	5.3	6.1	5.1	6.0
BIB - Bibra Lake	132	7.3	6.5	6.9	6.3
BP - British Petroleum	66	3.9	3.9	3.9	3.9
BPR - B.P. Refinery	132	12.6	13.8	11.3	12.5
BTY - Bentley	132	7.9	6.8	7.4	6.7
BYF - Byford	132	5.1	3.4	4.9	3.4
CBP-CSBP	132	12.5	13.6	11.3	12.4
CC - Cockburn Cement	132	9.2	7.9	8.6	7.5
CCL - Cockburn Cement Ltd	132	13.0	13.2	11.9	12.2
CKB - Cockburn Power	132	14.1	16.1	12.8	14.7
CL - Clarence St	66	4.9	3.4	4.8	3.4
COL - Collier	66	4.8	3.4	4.6	3.2
CT - Cannington Terminal	66	0.6	0.5	0.6	0.5
CT - Cannington Terminal	132	2.3	1.5	2.3	1.5
CVE - Canning Vale	132	7.9	6.3	7.5	6.1
E - Edmund Street	66	6.8	5.8	6.6	5.7
G - Gosnells	132	10.2	9.6	9.6	9.1
GNI - Glen Iris	132	14.3	16.2	13.0	14.8
KDL - Kewdale	132	8.8	7.9	8.3	7.6
KDP - Kwinana Desalination Plant	132	13.9	15.9	12.5	14.4
KMK - Kerr McGee Kwinana	132	13.0	15.2	12.3	14.3
KND - Kwinana Donaldson Road	132	13.4	15.4	12.0	13.9
KNL - Kenwick Link	132	6.8	7.6	6.5	7.3
KNL - Kenwick Link	330	2.4	2.5	2.3	2.4
KPP - Kwinana Power Partnership	132	12.3	13.3	12.0	12.1
KW - Kwinana	66	2.6	2.6	2.6	2.6
KW - Kwinana	132	5.5	5.8	5.3	5.6
KW - Kwinana	330	4.4	3.7	4.2	3.6
LTH - Leath Road	132	11.8	12.6	2.6	11.8
MDN - Maddington	132	8.3	7.7	7.9	7.3
MED - Medina	132	5.6	4.3	10.7	4.2
MH - Mandurah	132	5.0	3.7	5.4	4.2

		Current Levels (0 years)		Future Levels (5 years)	
Substation	Voltage (kV)	Fault level 3-phase (kA)	Fault level 1-phase (kA)	Fault level 3-phase (kA)	Fault level 1-phase (kA)
MSR - Mason Road	132	0.7	0.9	5.6	5.0
MSS - Meadow Springs	132	5.3	4.8	5.2	4.8
MUR - Murdoch	132	6.2	5.3	5.9	5.1
MYR - Myaree	66	4.4	3.0	4.3	3.0
OC – O'Connor	66	6.6	6.2	6.5	6.0
OFE - Office Road	132	12.2	13.0	11.1	11.9
PLD - Parklands	132	8.2	8.1	7.9	7.8
PNJ - Pinjarra	132	2.1	1.4	2.1	1.4
RO - Rockingham	132	7.9	7.0	5.2	6.8
RTN - Riverton	132	7.2	5.4	6.9	5.2
RVE - Rivervale	132	8.7	7.7	8.2	7.4
SF - South Fremantle	132	3.3	2.2	3.2	2.2
SF - South Fremantle	66	5.1	4.5	4.9	4.3
SNR - Southern River	132	8.8	7.3	8.4	7.0
ST - Southern Terminal	132	5.6	5.9	5.4	5.7
ST - Southern Terminal	330	4.0	3.8	3.6	3.4
TLA - Tianqi Lithium Australia	132	11.4	12.4	7.6	11.4
TPP- Tiwest Pigment Plant	132	13.8	16.3	12.3	14.6
VP - Victoria Pak	66	7.8	7.4	7.6	7.2
WAI - Waikiki	132	3.1	2.3	10.4	2.3
WE - Welshpool	132	7.4	6.4	7.1	6.1
WLN - Willetton	132	7.1	6.9	6.8	6.7
WM - Western Mining	132	6.5	5.9	3.1	5.7
North Region					
BGA - Badgingarra	132	4.5	1.8	4.1	1.7
CKN - Clarkson	132	5.3	4.5	4.6	4.1
CPN - Chapman	132	1.7	1.9	1.1	1.4
CTB - Cataby	132	3.4	3.5	2.6	2.9
EDG - Edgewater	132	11.5	12.3	9.8	10.7
EMD - Emu Downs	132	2.6	2.1	2.3	2.0
ENB - Eneabba	132	3.1	3.1	2.4	2.6
ENT - Eneabba Terminal	330	0.8	1.2	0.6	0.8
GGV - Golden Grove	132	1.1	0.8	1.0	0.8
GNN - Newgen Neerabup	330	5.8	6.0	4.9	5.3
GRS - Greenough River Solar Farm	132	2.7	3.1	1.7	2.1
GTN - Geraldton	132	1.4	1.9	1.0	1.4
HBK - Henley Brook	132	3.4	2.3	3.1	2.2
JDP - Joondalup	132	7.3	7.0	6.5	6.5
KMC- Kerr McGee Cataby	132	6.2	5.6	5.7	5.3
KMM - Kerr McGee Muchea	132	4.7	5.0	3.7	4.2
KRA - Karara Mine	330	8.8	7.6	7.3	6.7
LDE - Landsdale	132	1.6	1.6	1.4	1.4
MBA - Mumbida Wind Farm	132	1.2	1.6	1.7	1.8
MGA - Mungarra	132	1.9	2.5	0.9	1.3
MGS – Mungarra Solar Farm	132	1.9	2.5	0.9	1.3
MOR - Moora	132	1.0	0.7	0.9	0.7

		Current Levels (0 years)		Future Levels (5 years)	
Substation	Voltage (kV)	Fault level 3-phase (kA)	Fault level 1-phase (kA)	Fault level 3-phase (kA)	Fault level 1-phase (kA)
MUC - Muchea	132	8.5	7.0	7.1	6.3
MUL - Mullaloo	132	8.8	8.6	8.0	8.0
NBT - Neerabup Terminal	132	9.3	9.0	7.6	7.8
NBT - Neerabup Terminal	330	0.6	0.9	0.5	0.7
NOW - Nowergup	132	9.5	9.3	8.0	8.2
NT - Northern Terminal	132	1.1	0.8	1.1	0.8
NT - Northern Terminal	330	5.0	5.2	4.3	4.6
PBY - Padbury	132	7.3	6.1	6.7	5.8
PJR - Pinjar Power Station	132	5.3	4.7	6.7	4.4
RAN - Rangeway	132	1.7	1.9	1.1	1.4
RGN - Regans	132	2.0	1.8	1.7	1.6
TS - Three Springs	132	2.8	2.8	1.8	2.0
TST - Three Springs Terminal	132	2.7	2.6	1.8	2.0
TST - Three Springs Terminal	330	1.6	2.0	1.5	1.9
WDW - Warradarge Wind Farm	330	2.3	2.6	2.0	2.2
WGA - Wangara	132	7.4	6.8	6.8	6.4
WNO - Wanneroo	132	8.6	8.5	7.6	7.7
WWF - Walkaway Wind Farm	132	0.9	1.0	0.9	1.0
YDT - Yandin Terminal	330	0.7	1.0	0.5	0.8
YDW - Yandin Wind Farm	330	3.0	3.1	2.6	2.8
YP - Yanchep	132	5.8	5.2	5.3	4.9
South Region					
ALB - Albany	132	0.7	0.7	0.7	0.7
APJ - ALCOA Pinjarra	330	4.1	3.3	5.9	5.5
APJ - ALCOA Pinjarra	132	4.2	3.4	6.5	6.0
BDP- Binningup Desalination Plant	132	8.2	7.0	8.1	6.9
BGM - Boddington Gold Mine	132	7.4	7.5	7.2	7.3
BLW - Bluewaters Terminal	330	5.0	5.0	4.8	4.4
BNP - Beenup	132	1.0	0.8	1.0	0.8
BOD - Boddington	132	6.8	6.5	6.6	6.3
BSI- Barrack Silicon Smelter	132	10.0	9.5	9.8	9.3
BSN - Busselton	66	1.3	1.0	1.6	1.5
BSN - Busselton	132	0.8	1.0	0.8	1.0
BTN - Bridgetown	132	2.6	1.9	2.6	1.9
BUH - Bunbury Harbour	132	2.2	1.5	2.2	1.5
BWP - Bluewaters Power Station	330	7.3	7.9	6.7	7.1
CAP - Capel	66	2.1	1.4	2.1	1.4
CO - Collie	66	1.2	0.9	1.2	0.9
CPS - Collie Power Station	330	8.4	7.8	7.9	7.1
KAT - Katanning	66	0.5	0.3	0.5	0.3
KEM - Kemerton	132	2.4	1.8	9.7	10.4
KEM - Kemerton	330	4.0	3.2	5.9	5.8
KMP - Kemerton Power Station	330	8.0	7.6	7.4	7.0
KOJ - Kojonup	66	1.4	1.5	1.4	1.5
KOJ - Kojonup	132	1.7	2.0	1.7	2.0
LWT - Landwehr Terminal	330	3.7	4.0	3.4	3.7

		Current Levels (0 years)		Future Levels (5 years)	
Substation	Voltage (kV)	Fault level 3-phase (kA)	Fault level 1-phase (kA)	Fault level 3-phase (kA)	Fault level 1-phase (kA)
MBR - Mount Barker	132	0.6	0.7	0.6	0.7
MJP - Manjimup	132	1.6	1.3	1.6	1.3
MR - Margaret River	66	1.3	1.0	1.3	1.0
MRR - Marriott Road	132	9.4	9.0	9.3	8.7
MU - Muja	66	0.7	0.5	0.7	0.5
MU - Muja	132	0.9	0.8	0.9	0.8
MU - Muja	220	3.0	3.2	2.9	3.1
MU - Muja	330	4.3	4.1	4.1	3.8
NGN - Narrogin	66	1.1	1.4	1.1	1.4
NGS - Narrogin South	220	0.6	0.6	0.6	0.6
OLY - Oakley	330	0.9	1.1	0.9	1.1
PIC - Picton	66	1.5	1.1	1.5	1.1
PIC - Picton	132	2.0	2.2	2.0	2.2
SHO - Shotts	330	5.4	6.1	5.0	5.6
WAG - Wagin	66	0.6	0.5	0.6	0.5
WAPL- Worsley Alumina Pty Ltd	66	3.5	3.9	3.5	3.9
WAPL- Worsley Alumina Pty Ltd	132	7.7	8.7	7.6	8.5
WCG- Worsley Co Generation	132	9.5	11.1	9.4	10.9
WCL -Western Collieries Limited	132	3.5	2.9	3.5	2.8
WGP - Wagerup	132	2.9	2.0	2.8	2.0
WGP - Wagerup	330	3.7	4.0	3.4	3.7
WLT - Wells Terminal	132	6.6	7.0	6.4	6.7
WLT - Wells Terminal	330	4.3	3.5	4.2	3.4
WOR - Worsley	132	7.1	8.8	7.1	8.7
WSD - Westralian Sands	66	4.0	3.5	4.0	3.5
WSD - Westralian Sands	66	4.0	3.5	4.0	3.5

Appendix D: Transmission SSB Performance – System level

[Editor note: The table in this section for 2022/23 will be updated before the final TSP is published on 1 October 2023. Information is not available until September 2023]

Western Power is obligated under its transmission licence to comply with the Access Code and meet the minimum service levels defined by the Service Standard Benchmarks (SSB's) that are approved under each Access Arrangement period.

Western Power plans the transmission network to meet these SSBs for the following service standard benchmarks, covering reliability and security of supply for users directly connected to the transmission network:

- Circuit Availability – the availability of the transmission network, measured by the actual number of hours the transmission network circuits are available, divided by the total possible hours available (after exclusions).
- LoSEF – the frequency (per year) of unplanned customer interruption events where the loss of supply:
  - exceeds 0.1 but less or equal to 1.0 System Minutes Interrupted (SMI)
  - exceeds 1.0 System Minutes Interrupted.
- Average Outage Duration – the total number of minutes duration of all unplanned interruptions on the transmission network divided by the number of unplanned interruption events (after exclusions).

The data below in **Table 46** is to be reviewed and updated prior to publishing the final version of the TSP 2023

Table 46: Transmission service standard performance

Service Standard	SSB	2019/20 actual	2020/21 actual	2021/22 actual	2022/23 actual	AA SSB met	Comments
Circuit Availability	≥ 97.8%	98.8%	98.5%	98.9%	TBA	✓	Performance exceeded the AA4 benchmark and remained stable over the period.
Average Outage Duration	≤ 1,234	751	976	590	TBA	✓	Performance exceeded the AA4 benchmark and remained stable over the period
SMI LoSEF >0.1 and <= 1.0	≤ 26	15	14	5	TBA	✓	Performance exceeded the AA4 benchmark, with the 2021/22 period experiencing a significant improvement to past periods. The restoration of customers via the distribution system helped to maintain performance within benchmark.

Service Standard	SSB	2019/20 actual	2020/21 actual	2021/22 actual	2022/23 actual	AA SSB met	Comments
SMI LoSEF >1.0	≤ 7	3	2	7	TBA	✓	Performance was within the AA4 benchmark but declined compared to the 2020/21 period. A number of reasons contributed to the decline in performance, including: storm activity affecting a number of transmission lines bushfire and pole top fires events on the Network