Transgrid

People. Power. Possibilities.

System Security Roadmap Operational Technology Upgrades

RIT-T Project Specification Consultation Report

Issue date: 14 October 2024

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Executive summary

We are applying the Regulatory Investment Test for Transmission (RIT-T) to options for Transgrid's System Security Roadmap (SSR) Operational Technology (OT) contingent project, to upgrade operational technology and tools for use in our control rooms and corporate offices.

The Australian Energy Regulator (AER) accepted the SSR operational technology project as a contingent project for Transgrid's 2023-28 regulatory period, subject to the successful completion of early works and fulfilling specific trigger events.[1]

One of the trigger events identified by the AER for the contingent project application was the completion of a RIT-T. Alongside written support from the Australian Energy Market Operator (AEMO[2]), this RIT-T demonstrates that an investment in technological upgrades and tools is the preferred option to address the increasingly complex operational challenges faced by Transgrid.

Publication of this Project Specification Consultation Report (PSCR) represents the first step in the RIT-T process.

Project context: operational challenges in a transitioning power system

The electricity system in NSW is currently undergoing a period of transformation, with several factors driving increased complexity in power system planning and operations.

Historically, the consistent output profile of base load generators helped transmission network operators stabilise the technical operating envelope of the power system to quickly return the system to secure operations following contingency incidents (generator trips, equipment failures, weather events, etc). However, the NSW power system is now undergoing a transition from a small number of large, centrally distributed thermal generators to many small, distributed, variable generator connection and storage resources. At the same time there is also a growth in smart devices on our network as well as more active distribution networks feeding into the transmission network. Whilst all these developments will ultimately benefit consumers through increased access to lower cost, zero emission energy sources and the ability for the network to operate more flexibly overall to meet demand, they also increase the complexity of the system Transgrid needs to manage.

This transition is driving a substantial increase in information and analysis requirements across our operational control and operational planning functions, particularly due to an increase in the number and new types of transmission assets, in combination with unprecedented changes in generation and load interacting with our network. Additional complexity also arises from the more variable characteristics defining renewable generation and storage (compared to retiring base load generation).

In the absence of an upgrade to the capabilities used in our control rooms and corporate offices, the increasing complexity of the NSW power system means that:

- it is likely that Transgrid will need to impose constraints more frequently on the operation of the power system in NSW, and generally begin to operate the system in a more conservative manner (which may require placing constraints on the operation of low cost, renewable generators), to have sufficient confidence that the system will remain within its required operating envelope; and

1 AER, *Transgrid transmission determination – 1 July 2023 to 30 June 2028 – Attachment 5: Capital expenditure*, Final decision, p. 47.
2 AER, *Transgrid transmission determination – 1 July 2023 to 30 June 2028 – Attachment 5: Capital expenditure*, Final decision, p. 40.

- there is an increased likelihood that contingency events may occur when our operators are overburdened from needing to access and confirm the accuracy of information from multiple sources, and therefore less equipped to take the action within the required time. This in turn poses a greater risk of expected unserved energy (EUE) to end consumers going forward.

Transgrid would like to address these potential adverse outcomes proactively, and this RIT-T is being carried out to provide us with the tools to prevent such a situation from arising.

Identified need: net market benefits arising from investment in operational technologies and tools for use in control rooms and corporate offices

The investments considered in this RIT-T are expected to address limitations in the way in which we operate the network going forward. We expect market benefits will predominately arise from:

- reduced expected unserved energy (EUE), resulting from reduction in the risk of contingency events escalating to point where load shedding is required; and
- reduced dispatch costs and reduced greenhouse gas emissions, resulting from the ability to operate the system with fewer constraints on low-cost and low-emission renewable generation.

Our initial assessment indicates that the market benefits from enhancing the capabilities of operational technology (OT) systems (including our SCADA system) in our control room and corporate offices are expected to exceed the costs of these investments. As such, we have identified this as a 'market benefits' driven RIT-T (i.e., as opposed to a 'reliability corrective action' to address regulatory or service standard obligations).

Notwithstanding, continued investment in operational technology and tools is also likely to be integral to Transgrid continuing to meet our regulatory obligations under the National Electricity Rules (NER) in relation to the secure operation of the system under an increasingly complex operating environment.

The proposed investments are also important to meet AEMO's expectations as it considers the need to ensure system resilience in the face of the energy transition and increasing complexity of the system. Transgrid is working closely with AEMO in considering the interaction of our enhanced control room capabilities with the wider needs of the system. In particular, we are exploring options that align with AEMO's Operations Technology Roadmap[3] and Engineering Roadmap,[4] and which are consistent with the experience of system and market operators globally.

Three credible options have been identified at this early stage in the RIT-T process

We have undertaken early works to further investigate and develop alternative options for improving our control systems and corporate office capabilities. This has involved extensive investigation and planning by our internal teams, as well as the commissioning of expert input from independent international and Australian experts (Electric Power Research Institute (EPRI) and GHD Advisory).

As a result of these early works, we have identified three feasible options from a technical, commercial, and project delivery perspective that can be implemented in sufficient time to meet the identified need:

[3] AEMO, *Operations Technology Roadmap, available at: https://aemo.com.au/en/initiatives/major-programs/operations-technology-program/operations-technology-roadmap, accessed 19 September 2024.*
[4] AEMO, *Engineering Roadmap to 100% Renewables, available at: https://aemo.com.au/en/initiatives/major-programs/engineering-roadmap, accessed 19 September 2024.*

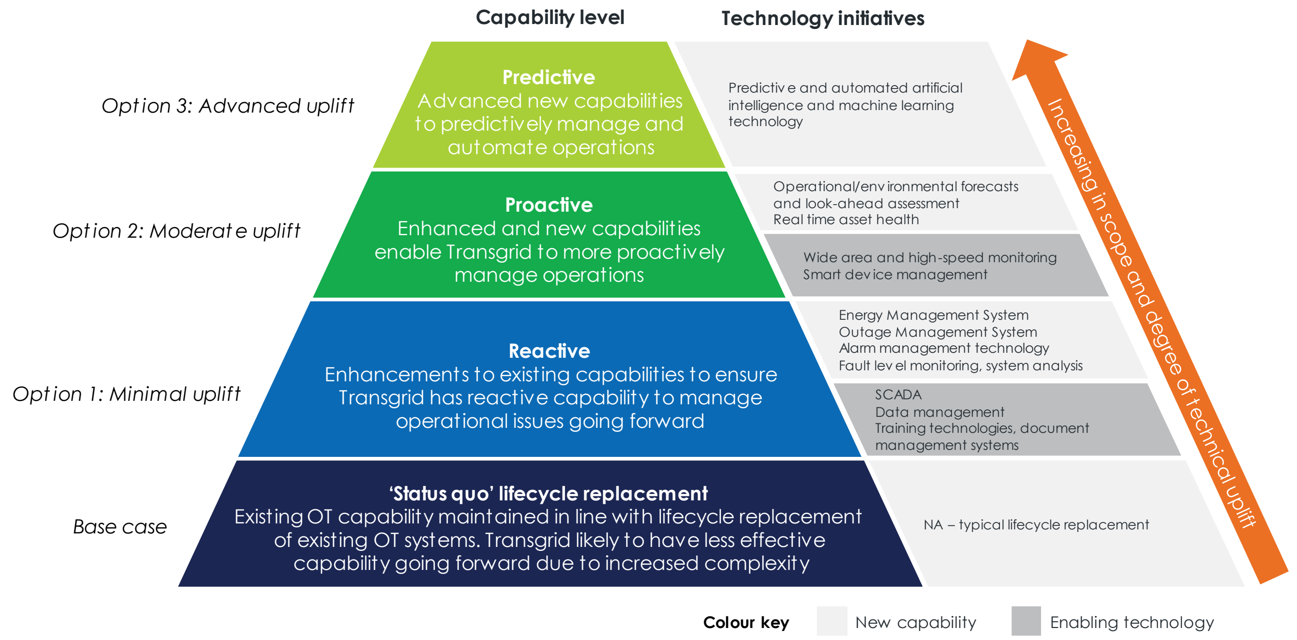
- Option 1: **Reactive capability –** provides enhancements to Transgrid's existing core OT capabilities (beyond typical lifecycle replacement capability) to improve the reactive capabilities of Transgrid's control room and corporate offices;
- Option 2: **Proactive capability –** provides further, moderate enhancements across a portfolio of Transgrid's existing OT capabilities, as well as additional new capabilities, so that Transgrid can proactively plan for, and respond to, operational issues across its control room and corporate offices; and
- Option 3: **Predictive capability** – provides a suite of advanced enhancements to existing capabilities, as well as adding advanced new capabilities, to enable Transgrid to employ a predictive approach to operations in our control room and corporate offices.

Each option comprises and builds upon the preceding option, ie, Option 2 includes the initiatives and capabilities in Option 1, typically at a higher level of technical uplift. In other words, the options increase in scope, capability and the degree of technical uplift. The implementation of technology initiatives under each option are staged to prioritise the initiatives required most urgently to meet the needs of an evolving power system.

The three options have been developed as a package to reflect the minimum incremental technology solution required to enable a defined level of capability (i.e., reactive, proactive, predictive). As a result, partial implementation of an option would not result in the intended capability being achieved.

The differing features of the options are illustrated in Figure E-1E-1 below, which summarises the key characteristics of the three options, in terms of the capabilities, associated technology and the extent of technical uplift.

Figure E-1: Option capability-technology pyramid



Note: In addition to the technology initiatives identified above, operational planning sits across several of the technology initiatives as an enabling and complementary function.

We are undertaking a market testing process (through the issuing of a Request for Information to potential vendors) to confirm the availability and costing of the options being considered, and to test whether there are other credible options that should be considered in this RIT-T. The results of this market testing will be considered in the analysis presented in the Project Assessment Draft Report (PADR).

Estimated capital costs for each option are summarised in Table E-1E-1 below. Transgrid will be undertaking further work (including drawing on the market testing process) to refine these cost estimates prior to the PADR assessment.

Table E-1: Summary of credible options and capital costs $m (+/- 25%)

Option	Capability	Scope	Capital cost
Option 1	Reactive capability	Enhancements to Transgrid's existing core OT capabilities	77.9
Option 2	Proactive capability	Moderate enhancements across a portfolio of Transgrid's existing OT capabilities, as well as additional new capabilities	110.1
Option 3	Predictive capability	Advanced enhancements to existing capabilities, as well as additional advanced new capabilities	131.6

Transgrid is very mindful that its expenditure needs to be efficient. In further refining the options, and in considering the additional revenue we request in our contingent project application, we are investigating the potential to achieve synergies with works being considered by AEMO and other Network Service Providers, as well as ensuring that our incremental revenue request takes into account the revenue that has already been included by the AER in our current regulatory determination.

Non-network options are not expected to be able to assist with this RIT-T

We do not consider non-network options to be commercially and technically feasible to assist with meeting the identified need for this RIT-T.

Non-network options (which typically include options such as local generation and/or demand management) are unable to contribute towards meeting the identified need for this RIT-T, as these options cannot affect the capabilities of Transgrid's control rooms or corporate offices. There are currently no known non-network alternatives that could effectively augment or substitute for the investments that Transgrid is proposing.

Submissions and next steps

The purpose of this PSCR is to set out the reasons we propose that action be undertaken, present the options that address the identified need, outline why for this particular RIT-T we do not consider non-network options are able to assist, and allow interested parties to make submissions and provide input to the RIT-T assessment.

We welcome written submissions on materials contained in this PSCR. Submissions are due on 15 January 2025.

Submissions should be emailed to our Regulation team via regulatory.consultation@transgrid.com.au.[5] In the subject field, please reference 'System Security Roadmap Operational Technology upgrades PSCR'.

[5] We are bound by the *Privacy Act 1988 (Cth)*. In making submissions in response to this consultation process, we will collect and hold your personal information such as your name, email address, employer and phone number for the purpose of receiving and following up on your submissions. If you do not wish for your submission to be made public, please clearly specify this at the time of lodgement. See Privacy Notice within the Disclaimer for more details.

At the conclusion of the consultation process, all submissions received will be published on our website. If you do not wish for your submission to be made public, please clearly specify this at the time of lodgement.

We intend to produce a Project Assessment Draft Report (PADR) that addresses all submissions received and presents our draft conclusion on the preferred option for this RIT-T. Subject to what is proposed in submissions to this PSCR, we anticipate publication of a PADR in early 2025.

Contents

1. Introduction

We are applying the Regulatory Investment Test for Transmission (RIT-T) to options for Transgrid's System Security Roadmap (SSR) operational technology contingent project, to upgrade operational technology and tools for use in our control rooms and corporate offices. Publication of this Project Specification Consultation Report (PSCR) represents the first step in the RIT-T process.

In our 2023-28 revised regulatory proposal, we proposed additional investment in operational tools to plan, maintain and operate the power system as New South Wales (NSW) transitions towards 100 per cent renewable generation.[6] However, at that time, the Australian Energy Regulator (AER) determined that we had not yet demonstrated the need for investing in the SSR operational technology project.[7] After consultation and resubmission, the AER accepted the SSR operational technology project as a contingent project for Transgrid's 2023-28 regulatory period, subject to the successful completion of early works and fulfilling specific trigger events.[8]

One of the trigger events identified by the AER for the contingent project application was the completion of a RIT-T. Alongside written support from the Australian Energy Market Operator (AEMO[9]), this RIT-T demonstrates that an investment in technological upgrades and tools is the preferred option to address the increasingly complex operational challenges faced by Transgrid.

We are currently in a period of transformation for the electricity system in NSW, with several factors driving increased complexity in power system planning and operations. In the absence of an upgrade to the capabilities used in our control rooms and corporate offices:

- it is likely that Transgrid will need to impose constraints more frequently on the operation of the power system in NSW, and generally begin to operate the system in a more conservative manner, to have sufficient confidence that the system will remain within its required operating envelope; and
- there is an increased likelihood that contingency events may occur when our operators are overburdened from informational overload, arising from the additional complexity of the system, and therefore less equipped to take the action required in response. This in turn poses a greater risk of expected unserved energy (EUE) to end consumers going forward.

We have identified the opportunity to deliver significant market benefits from upgrading operational technology and tools for use in our control rooms and corporate offices to address these expected limitations in the way in which we operate the network going forward. The proposed project is expected to result in an overall increase in net economic benefits, as captured in the RIT-T. As such, we have identified this as a 'market benefits' driven RIT-T (i.e., as opposed to a 'reliability corrective action' to address regulatory or service standard obligations).

Notwithstanding the net economic benefits expected to arise from undertaking this investment, we note that continued investment in operational technology and tools is also likely to be integral to Transgrid continuing to meet our regulatory obligations under the National Electricity Rules (NER) in relation to the secure operation of the system under an increasingly complex operating environment.

6 Transgrid, *2023-28 Revised Regulatory Proposal*, December 2022, pp 53 and 54.
7 AER, *Transgrid transmission determination – 1 July 2023 to 30 June 2028 – Attachment 5: Capital expenditure*, Final decision, p. 26.
8 AER, *Transgrid transmission determination – 1 July 2023 to 30 June 2028 – Attachment 5: Capital expenditure*, Final decision, p. 47.
9 AER, *Transgrid transmission determination – 1 July 2023 to 30 June 2028 – Attachment 5: Capital expenditure*, Final decision, p. 40.

The proposed investments are also important to meet AEMO's expectations as it considers the need to ensure system resilience in the face of the energy transition and increasing complexity of the energy system. Transgrid is working closely with AEMO in considering the interaction of our enhanced control room capabilities with the wider needs of the system. We are exploring options that align with AEMO's Operations Technology Roadmap[10] and Engineering Roadmap,[11] and which are consistent with the experience of network, system and market operators globally and from across Australia.

The contingent project trigger event requires AEMO's written support for implementing the preferred option identified in the RIT-T.[12] Transgrid will be working closely with AEMO throughout the RIT-T process to consider the interaction of our enhanced control room capabilities with the wider needs of the system, and to ensure AEMO's support prior to the publication of the PADR for the preferred option identified in the RIT-T. Subsequently, Transgrid will seek AEMO's written support for the OT tools uplift as part of the trigger for the CPA submission.

As input into the preparation of this document, Transgrid has supported and collaborated with AEMO on the development of the General Power System Risk Review (GPSRR). This review led by AEMO, supports our ability as an industry to review and operate resilient power systems into the future. In addition, AEMO provided input into an independent assessment conducted by EPRI (Electrical Power Research Institute) to validate and prioritise the operational capabilities and tools required by Transgrid to meet the evolving operational needs of the control room. Transgrid continues regular engagements with AEMO to keep aligned at various levels between the organisations.

1.1. Purpose of this report

The purpose of this PSCR[13] is to:

- set out the reasons why we propose that action be undertaken (the 'identified need');
- present the options that we currently consider address the identified need;
- outline the technical characteristics that non-network options would need to provide (although we note that non-network options are not expected to be able to form part of a potential credible option for meeting the identified need for this RIT-T);
- outline our proposed approach to the RIT-T assessment, including identifying the classes of market benefit we expect to be material; and
- allow interested parties to make submissions and provide inputs to the RIT-T assessment.

Overall, this report provides transparency into the planning considerations for investment options to enhance the capabilities of our control room and corporate offices. A key purpose of this PSCR, and the RIT-T more broadly, is to provide interested stakeholders the opportunity to review the analysis and assumptions, provide input to the process, and have certainty and confidence that the preferred option has been robustly identified as optimal.

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[10] AEMO, *Operations Technology Roadmap*
[11] AEMO, *Engineering Roadmap to 100% Renewables*
[12] AER, *Transgrid transmission determination – 1 July 2023 to 30 June 2028 – Attachment 5: Capital expenditure*, Final decision, p. 40.
[13] See Appendix A for the National Electricity Rules requirements.

1.2. Submissions and next steps

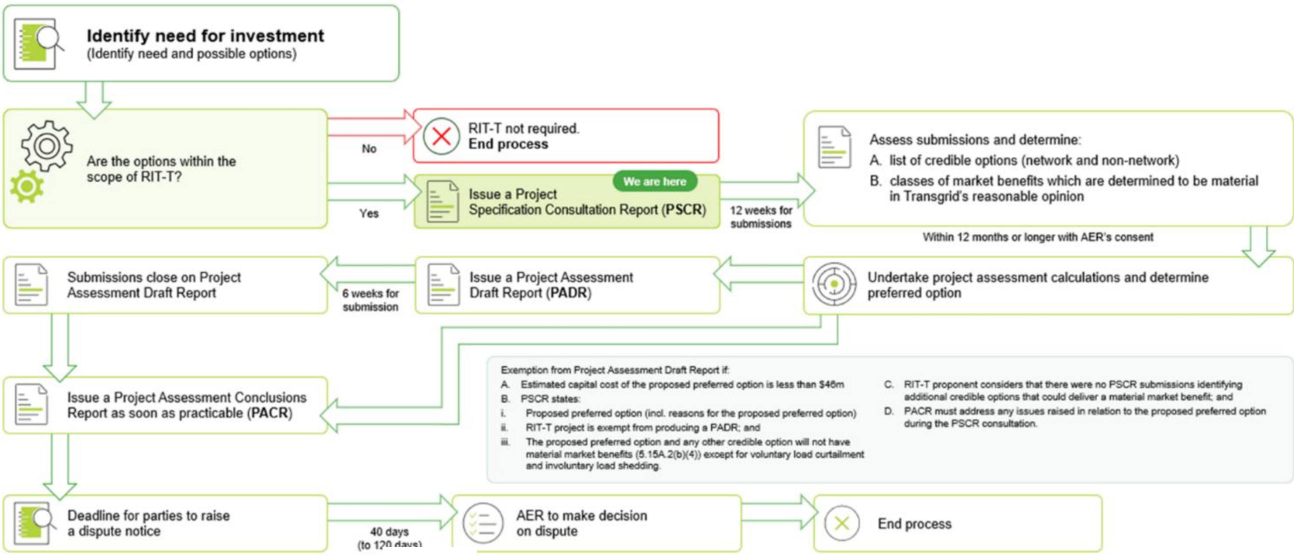
We welcome written submissions on materials contained in this PSCR. Submissions are due on 15 January 2025.

Submissions should be emailed to our Regulation team via regulatory.consultation@transgrid.com.au.[14] In the subject field, please reference 'System Security Roadmap Operational Technology upgrades PSCR'.

At the conclusion of the consultation process, all submissions received will be published on our website. If you do not wish for your submission to be made public, please clearly specify this at the time of lodgement.

We intend to produce a Project Assessment Draft Report (PADR) that addresses all submissions received and presents our draft conclusion on the preferred option for this RIT-T. Subject to what is proposed in submissions to this PSCR, we anticipate publication of a PADR in early 2025.

Figure 1-1 This PSCR is the first stage of the RIT-T process[15]



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[15] AEMC, *Replacement expenditure planning arrangements, Rule determination*, 18 July 2017.

2. The identified need

This section outlines the identified need for this RIT-T and the assumptions and data underpinning it. It also sets out background information related to the identified need and the expected drivers of net market benefits arising from the proposed investments in operational tools.

2.1. Description of the identified need

The identified need for this RIT-T is to increase overall net market benefits in the NEM as the complexity of the electricity system increases, by:

- avoiding the need to impose constraints on the operation of generators connected to our system more frequently going forward in order to ensure the system remains within its required operating envelope. This includes avoiding the need to impose constraints during periods of planned and unplanned outages, including outages necessary to connect new generation and undertake network upgrades, that are likely to otherwise need to occur; and
- allowing our control system operators to better prepare for, and then assess and respond to, contingency events in an increasingly complex operating environment with a substantive increase in information sources needing to be monitored, which is expected to reduce the likelihood of load shedding (ie, expected unserved energy).

In particular, we expect market benefits from reduced expected unserved energy (EUE), reduced dispatch costs, and reduced greenhouse gas emissions, resulting from reduction in the risk of contingency events escalating to point where load shedding is required, and the ability to operate the system with fewer constraints predominately on low-cost or low-emission renewable generation.

Our Project Assessment Determination Report (PADR) will detail the extent and scope of expected market benefits. Our initial assessment indicates that the market benefits from enhancing the capabilities of our operational technology (OT) systems (including our SCADA[16] system) in our control room and corporate offices are expected to exceed the cost of the proposed investments in operational technologies, when compared to the base case. We have therefore presented this as a 'market benefits' driven RIT-T (i.e., as opposed to a 'reliability corrective action' to address a prescribed regulatory obligation).

Notwithstanding the expected net benefits, the proposed enhancements to our control room and corporate office capabilities are also integral to Transgrid continuing to meet our obligations under the NER. This includes our obligations to maintain a secure operating state, and return the system to a secure operating state, following a contingency event or change in power system conditions.[17] Our ongoing compliance with our NER obligations is being challenged by the decentralisation of generation, a higher proportion of intermittent generation, and new network and non-network technologies interacting with our network.

Under NER 4.1.12(a), Network Service Providers are required to provide and maintain, in accordance with applicable standards, the necessary primary and, where nominated by AEMO, back-up communications facilities for control, operational metering and indication from the relevant local sites to the appropriate interfacing termination as nominated by AEMO. We note that the AER's compliance and enforcement priorities for 2024-25 included the improvement of market participants' compliance with standards for

[16] Supervisory control and data acquisition.
[17] Clause 4.2.6 of the National Electricity Rules, v 216.

critical infrastructure.[18] In particular, the AER highlighted the need for Transmission Network Service Providers (TNSPs) to comply with obligations in the NER and connection agreements in relation to SCADA infrastructure.[19] In general, the increasing complexity of the system will challenge Transgrid in maintaining our compliance with these obligations under status quo operating procedures.

The proposed investments also align with the expectations of AEMO, which also faces increased operational complexity due to the energy transition. The investments proposed in this RIT-T are complementary to AEMO's workstreams to improve its own ability to handle increased renewable penetration in the NEM, including its Engineering Roadmap and Operational Technology Roadmap (discussed further below). AEMO's operations depend on Transgrid maintaining an appropriate level of operational capability, especially with regard to provision of real-time data from SCADA systems that interface directly with AEMO. As system complexity across the NEM grows, we anticipate AEMO's reliance on Transgrid's operational capability will continue to increase. In addition, Transgrid has broader operational responsibilities under the National Electricity Rules (NER 4.3.1) and outlined within the AEMO/ Transgrid Schedule of Delegation[20] that maintain as system complexity increases.

2.2. Background to the identified need

The energy transition in NSW is occurring at a rapid pace and is driving increased complexity in power system operations and planning. The next decade will be a period of profound transformation within the electricity system, in both NSW and across the NEM.

The NSW power system is undergoing a transition from a small number of large, centrally distributed thermal generators to a large number of small, distributed, variable generator connection and storage resources. Currently the NSW power system is underpinned by large, thermal generators that supply over 60 per cent of generation on the transmission network. These thermal generators are nearing the end of their operational lives. In particular, the majority of coal generators in NSW are scheduled to retire within the next decade, including Eraring Power Station in 2027, and Bayswater Power Station and Vales Point Power Station by 2033.[21] AEMO's most likely 'step change' ISP scenario forecasts that 6.9 GW of coal generation capacity in NSW will retire between 2024/25 and 2031/32, i.e., over 80 per cent of current coal capacity.[22]

Historically, these generators have typically operated as 'base load' generators, situated close to major demand centres, with units providing stable and reliable supply over a predictable output profile. This has provided certainty to network operators and has assisted operators to stabilise the technical operating envelope of the power system and quickly return the system to secure operations when incidents occur on the network (generator trips, equipment failures, weather events, etc.).

As base load thermal generation retires, it is expected that variable renewable generation (VRE), energy storage and firm (peaking) capacity will be rapidly deployed so that there will continue to be sufficient generation to meet demand. Renewable generators typically have a lower capacity and are more geographically distributed compared to the retiring base load thermal generators. As a consequence, the

[18] AER, *AER Compliance & Enforcement Priorities 2024 – 25*, June 2024, p 4.
[19] AER, *AER Compliance & Enforcement Priorities 2023 – 24*, June 2023, p 3.
[20] AEMO, *Schedule 1 – Extract from Transgrid instrument of delegation*
[21] AEMO, *2024 Electricity statement of opportunities*, August 2024, p. 10.
[22] AEMO, *2024 ISP generation and storage outlook workbook (Step Change, CD)*, August 2024, Summary sheet.

number of connections on our network is increasing rapidly, and we are interfacing with a significantly larger number of market participants. For example, in the eight years between 2015 and 2023:[23]

- The number of generator operators has increases from 9 to 41 (4 times more); and
- The number of generator connections has increases from 101 to 184 (~80% more).

In turn, increased connections and the number of generation operators is driving a substantial increase in information and analysis requirements across our operational control and operational planning functions. This arises from the increase in variables and interactions across our network, both from the number of participants, and the more variable (and less firm) characteristics which define renewable generation and storage.

We expect this trend to continue, with a corresponding impact on the workload and functions required to manage our network, particularly for our control centre and operational planning functions. For example, AEMO's step change scenario forecasts that variable renewable generation capacity in NSW (including utility scale and behind the meter) will more than double between 2024/25 and 2029/30, increasing from 15.1 GW in 2024/25 to 34.6 GW in 2029/30.[24] Grid-scale wind and utility solar capacity is forecast to grow to 22.5 GW in 2029/30, an increase of 15 GW from 2024/25.[25]

The NSW Government is driving this transformation through the NSW Electricity Infrastructure Roadmap, which sets out the plan for development of at least five Renewable Energy Zones (REZs) across NSW to facilitate the connection of an intended 12 GW of renewable generation capacity by 2030.[26] Figure 2-1 shows the expected REZ capacity of solar and wind generation in NSW over the next ten years under the 2024 ISP candidate development path (CDP) 9 (i.e., step change least cost without actionable New England REZ Transmission Link 1 nor New England REZ Extension).[27]

[23] Transgrid, *System Security Roadmap*, 21 June 2023, p 30

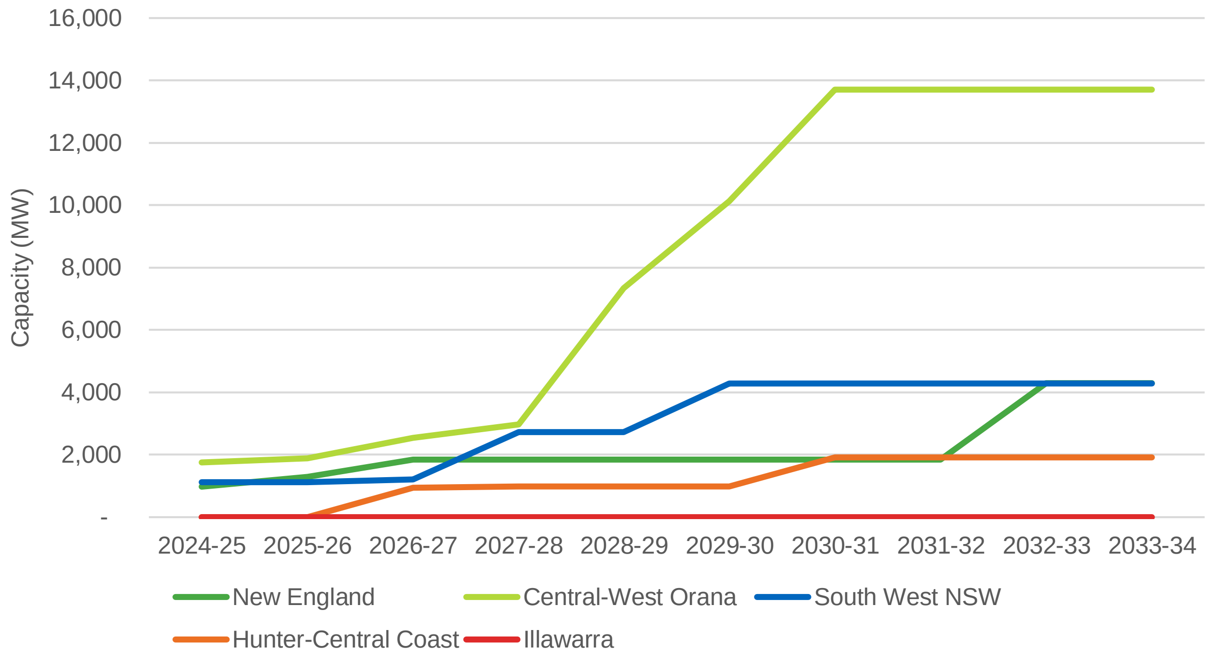
[24] AEMO, *ISP generation and storage outlook*, 26 June 2024, CDP9. Figure includes wind, solar and distributed PV.

[25] AEMO, *ISP generation and storage outlook*, 26 June 2024, CDP 9. Figure does not include distributed PV.

[26] New South Wales Government, *Electricity Infrastructure Roadmap*, see: https://www.energy.nsw.gov.au/nsw-plans-and-progress/major-state-projects/electricity-infrastructure-roadmap, accessed 13 September 2024. Includes: Central-West Orana, Illawarra, New England, South-West and Hunter-Central Coast regions of NSW.

[27] We note the 2024 ISP was prepared with CDP14 as the optimal development path (ODP), but subsequent news on the delay to New England REZ from September 2028 to June 2031 means that CDP9 is more likely to represent future generation capacity build.

Figure 2-1: Expected NSW REZ generation capacity



Source: AEMO, *ISP generation and storage outlook*, 26 June 2024, CDP9

Significant transmission links are also being developed in line with AEMO's ISP and are expected to come online in the next decade to transfer REZ generation to NSW consumers, further increasing operational complexities.[28]

With these significant changes on the network, operating conditions on the power system will change dramatically, to become more distributed, less stable and less predictable. By 2029/30, the average contribution of generation from intermittent, weather-driven sources is forecast to grow from 34 per cent to 66 per cent, while the proportion from thermal generation will fall from 62 per cent to less than 15 per cent, between 2024/25 and 2029/30, respectively.[29]

At the same time there is also a growth in smart devices on our network as well as more active distribution networks feeding into the transmission network. Whilst all of these developments will ultimately benefit consumers through increased access to lower cost, zero emission energy sources and the ability for the network to operate more flexibly overall to meet demand, they also increase the complexity of the system Transgrid needs to manage.

2.3. Increased complexity and reduced predictability are testing the limits of control centre capabilities

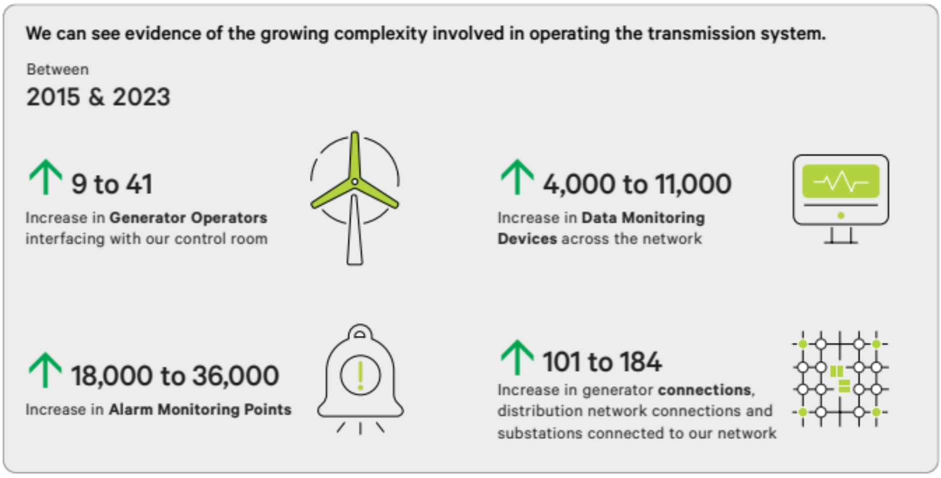
A key outcome of this profound shift in the energy system is that the challenges of operating the system will increase substantially, including the demands placed on the control rooms and the operational planners that manage the power system.

[28] AEMO, *2024 Electricity statement of opportunities*, August 2024, pp. 57 and 78.
[29] AEMO, *ISP generation and storage outlook*, 26 June 2024, CDP 9. Thermal generation includes black coal, brown coal and mid-merit gas.

The energy transition is well underway, with extensive system transformation forecast to occur in the next decade. However, system complexity and risks are already increasing and existing control room tools and capabilities are reaching their limits given the extent of change already experienced in recent years.

Transgrid has already experienced a substantial increase in the complexity of its network operation. Although there is no single metric to characterise the increasing complexity being borne by network operators and operational planners, Figure 2-2 below presents key increases in network parameters between 2015 and 2023, with all these parameters continuing and forecast to increase over the next decade, demonstrating the increase in operational complexity faced by our control rooms and operational planners.

Figure 2-2: Changes in operational parameters between 2015 and 2023



Source: Transgrid, *System Security Roadmap*, 21 June 2023, p 30.

Figure 2-3 below depicts the multiple information sources that our operators must navigate under an increasingly complex power system and illustrates how our system operators must currently maintain awareness of a variety of systems concurrently (including multiple screens and telephone communications), particularly during network critical operations such as switching.

Figure 2-3: Transgrid's system control room and current information and monitoring capabilities

Case study: Control centre alarm management

As the energy sector transitions to higher levels of renewable integration, our control room operators face an increasing number of alarms and alerts, increasing their cognitive load. This increase in alarm activity is driven by a range of factors including an increased number of connections, the network operating closer to the edge of the technical operational envelope and the variable nature of renewable energy sources, which require more dynamic monitoring and management.

Operators often handle multiple tasks simultaneously, including processing system alarms, phone calls and analysing real-time data from multiple systems. This is most acute during a problem on the network where operators need to quickly make the correct decision to ensure the safe, secure, reliable operation of the power system. In these complex and high-pressure environments, finding the correct information can be difficult. The more alarms that are triggered, the harder it becomes for operators to sift through the noise to focus on critical issues. Further, the volume of alarms compounds the difficulty faced by operators, making it harder for operators to respond effectively.

Investment in advanced alarm management systems is crucial to better manage the growing number of alarms. International standards, such as ISA-18.2 and IEC 62682, provide guidelines for the maximum number of alarms control rooms should process. These standards recommend that operators handle no more than a prescribed number of alarms per hour to avoid cognitive overload and ensure timely response. Currently our control centres exceed these standards. When this threshold is exceeded, the likelihood of errors and missed alarms is likely to increase.

Without proper intervention, the number of alarms is expected to further increase over time and risks overwhelming our operators, leading to two critical outcomes:

- Missed Alarms: Operators may fail to notice critical alarms, leading to the disconnection of assets to protect them. This can result in unserved energy, especially if the event aligns with a contingency violation, which is when the network element is operating without redundancy.
- Misinterpreted Alarms: Operators may take incorrect actions based on misinterpreted alarms, leading to the disconnection of assets or triggering cascading events.

2.3.1. AEMO is increasing its focus on system operability capabilities

AEMO is actively investigating how transmission network and system operators are positioned for the decentralisation of generation arising from the renewable transition.

AEMO's Engineering Roadmap to 100% Renewables intends to advance operational capability for times of high renewables, addressing engineering challenges from the energy transition before they emerge operationally and supporting market growth in renewables as the power system portfolio evolves.[30] AEMO has stated that its intention is to build operational readiness which is aligned with TNSPs' and other related industry initiatives.[31]

AEMO has outlined focus areas for operational capability as part of its Engineering Roadmap priority action reports. For instance, AEMO's FY2024 priorities included:[32]

- optimising AEMO's processes and governance for the management of power system data, models, and tools, including establishing data and model quality requirements in collaboration with NSPs; and
- developing and implementing an Operations Technology Roadmap to guide projects and investment required in AEMO's NEM and WEM operational technology, to enable safe, secure operation of the future power system.

Further, AEMO's latest FY2025 priority action also included actions to:[33]

- enable AEMO to manage a wider range of high variable renewable energy (VRE) and system conditions with greater certainty and less margin;
- support faster commissioning processes for new connections;
- facilitate timely risk identification and management of real-world conditions as the generation mix changes; and
- increase confidence in system behaviour to make better informed decisions during power system operation.

AEMO has also developed an Operational Technology Roadmap, which it continuously updates to identify gaps and solutions for the industry, as well as the market operation capabilities needed to enable transformative change while maintaining electricity system reliability, security and resilience. AEMO's focus on operability has been increasing, as the extent of the gaps between current capabilities and the capabilities needed for the future grows. AEMO is developing a 'control room of the future', reflecting the changed requirements for operational control centres. The control room of the future will reflect a secure, flexible, adaptable space where systems are integrated, interoperable and automated, all resources are maximised, and personnel are highly trained in simulators to make data-driven decisions based on accurate forecasts.[34] In April 2023, AEMO provided written support to the AER to support Transgrid's proposed investment in early works to develop advanced operational technology tools and capabilities. The letter stated, "Importantly, there are interdependencies between the roles of AEMO and Network Service Providers (NSPs) and systems and capabilities must effectively interface, support and compliment each other. Investments by AEMO alone will not be sufficient; a capability uplift will be needed by all system

[30] AEMO, *Engineering Roadmap – FY2025 priority actions report*, 15 August 2024, p. 3.
[31] AEMO, *Engineering Roadmap to 100% Renewables*, December 2022, p. 6.
[32] AEMO, *Engineering Roadmap – FY2024 priority actions report*, 12 July 2023, p. 22.
[33] AEMO, *Engineering Roadmap – FY2025 priority actions report*, 15 August 2024, p. 21.
[34] AEMO, *Operations technology program – operations planning working group*, 15 March 2023, p. 7.

operators in order for the system security to be maintained across the National Electricity Market (NEM). These investments are urgently needed to manage the security of the power system and to complement investments AEMO is making under its own Operations Technology Roadmap"

We consider that the investment proposed in this RIT-T will deliver complementary benefits to AEMO's initiatives to prepare for higher levels of renewable integration. In particular, we expect that the proposed investments will provide network operators with greater network visibility (ie, awareness) to ensure that the system remains within its secure operating envelope. As a consequence, they will enable Transgrid to operate the transmission assets within the power system with greater confidence and impose fewer constraints on the NSW network.

The triggers for the contingent project require AEMO's written support for the implementation of the specific operational technology upgrades and tools proposed by Transgrid.[35] Transgrid is working closely with AEMO to ensure alignment with improvements to our operational technology and to minimise unnecessary duplication of investment between organisations.

2.4. Drivers of expected market benefits

There are three principal drivers of expected market benefits as a result of upgrading the operational technology and tools in Transgrid's control rooms and corporate offices, resulting from:

- enhanced awareness and information availability to operators in the control room, across the short term operational horizon.
- improved outage planning across the short to medium term operational and planning horizons; and
- improved capability to manage the integration of new investments over a long term planning horizon.

2.4.1. Greater awareness amongst operators in the control room

A key driver of market benefits from the proposed investment is greater awareness of operational conditions for control room operators and operational planners across Transgrid's network.

As the power system becomes more distributed, dynamic and unpredictable there will be an almost exponential increase in real-time operational decision-making requirements. Conditions on the NSW power system will become more unpredictable, leading to more frequent manual operator actions, which all require careful planning and execution. This places a greater risk of human error when situational awareness is difficult and cognitive overload is high.

Transgrid has observed that the NSW power system is sitting closer to the edge of its secure operating envelope, with the increased complexity making the system more likely to tip into insecure operating conditions if a credible contingency occurs. As a result, making it more challenging for operators to return the power system to a secure state following a contingency event.

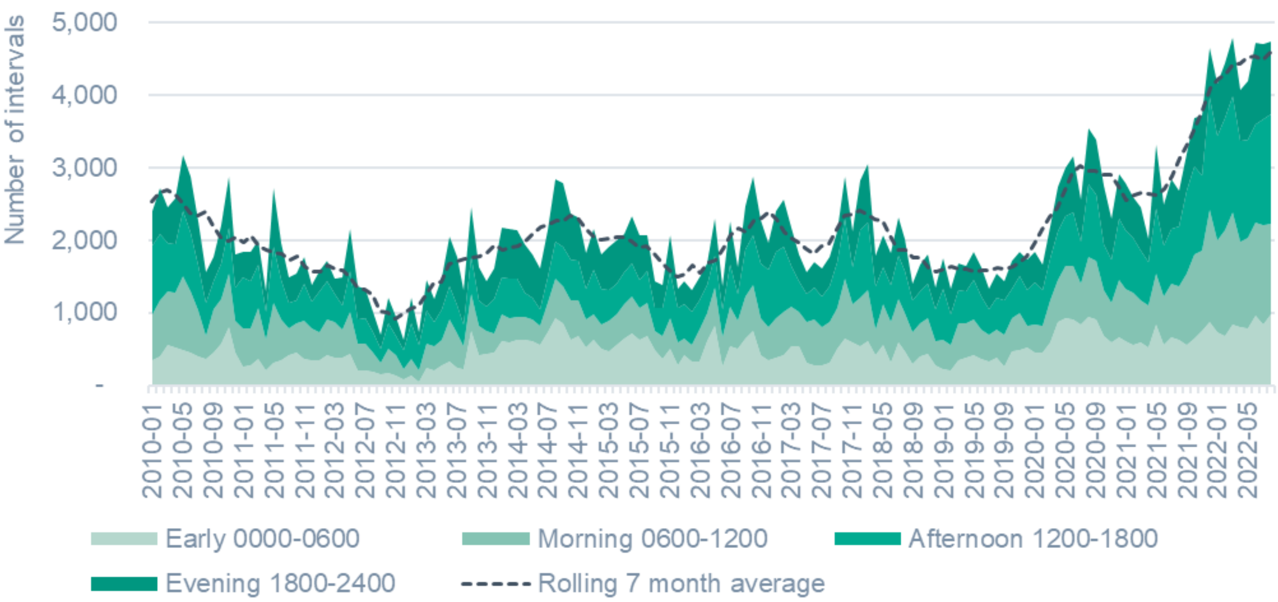
By way of example, Figure 2-4 presents the results of Transgrid's Contingency Analysis (CA) tool from 2010 to 2022. The CA tool uses the SCADA Energy Management System load flow scenarios for predefined credible contingencies, for each 5-minute dispatch period, of which there are between 8,064 to 8,928 dispatch periods a month. An alarm is raised whenever there is a part of the network without a level

[35] AER, *Transgrid transmission determination – 1 July 2023 to 30 June 2028 – Attachment 5: Capital expenditure*, Final decision, p. 40.

of redundancy to prevent breaching the operational technical envelop. In these situations, the control centre where possible reconfigures the network to restore the redundancy, however a credible contingency could result in insecure network operation, and without intervention this could cause network faults with lost generation and/or load, or potential escalation to a major (or catastrophic) system event. The frequency of these alarms has increased to occurring over 50% of the time and considered to be an indicator of system risk.

The trend in Figure 2-4 shows that the number of CA alarms grew significantly in the last two years of the analysis period, and more than doubled by 2022 compared to the average over the period 2010-2020. This highlights the increasing level of responsiveness (and possibly required intervention) that is already required in the Transgrid control room, and the reliance on operators making a growing number of decisions in real-time to maintain secure operations. This trend is forecast to continue as system complexity increases. Our existing tools, information levels and capabilities will not be able to scale to continue to effectively manage system security risk.

Figure 2-4: Operating intervals when at least one credible contingency on the NSW transmission system would have resulted in a violation of the power system technical envelope, 2010 to 2022



The high level of CA alarms has continued in the period following that shown in the figure.

Enhanced awareness and control capability in asset monitoring and grid operations will be required to identify critical network issues and alert operators to ensure secure operation of the network. In the absence of an enhancement of these capabilities, there is likely to be a need to impose more conservative asset operating parameters, as well as a higher risk of EUE due to the many decisions operators are required to make, based on multiple information sources, in the absence of the technology and systems upgrades considered in this RIT-T.

2.4.2. Improving outage planning

Until recently, the planning and operation of the power system has been largely deterministic. Lack of Reserve (LOR) conditions were rare and tended to occur during periods of consecutive hot days during summer months. Power system planning and operations to predict and manage network outages focused on single outage contingency (N-1), system peak demand, and managing voltage levels to support the balancing of supply and demand over a relatively predictable daily load profile. Existing tools, capabilities and resourcing levels reflect these conditions and requirements.

New risks and requirements have emerged for planning, operating and managing the transmission system. Incorrect or incomplete analysis, information or decision making can result in system security incidents on the network - if generation, network assets and services do not perform as planned, or if decisions are made on an incomplete or incorrect basis.

Multiple forecasts and system simulations will need to be run in the short to medium term to ensure that secure operations will be maintained in the event of network outages, factoring in availability of dispatchable generators, variable renewable generation, demand conditions and planned or predicted network outages. The quantity of information required to be considered exceeds the capabilities of our existing tools. There are also more market participants involved in planning and executing an outage. In addition, outage windows are shrinking due to an operating envelope which is less stable, requiring thorough planning to avoid late cancellations or frequent recalls, which can affect short-term market dispatch and delay the connection of new generation projects.

In the absence of an upgrade to capabilities to improve Transgrid's capacity to manage network outages, including outages associated with the connection of new renewable generation, there is likely to be either a need to reschedule outages (preventing the work from proceeding), and/or longer outage windows with sub-optimal network and market operating conditions.

2.4.3. Managing the integration of new investments

Multiple scenarios and contingencies will need to be tested to assess power system reliability and security, as coal units retire, as well as to connect and commission new renewable generation, transmission infrastructure and REZs.

Transgrid must facilitate the connection of very large volumes of new renewable generation and battery storage capacity, and growth in data centres to the NSW transmission network, including managing generator testing, energising and commissioning. Each of these stages involves detailed power system analysis to ensure that generators meet performance standards, and the power system can operate securely with them online under a range of different conditions and scenarios. Complex and unpredictable interactions between inverter-based generators, and between inverter-based generation and other system elements are possible, particularly as levels of system strength and other system security services decline. Failure to identify and mitigate these issues in the planning phase can result in system security and power quality issues once generators are operational.

Further, AEMO's 2024 ISP identifies several committed and actionable large-scale transmission projects required to be developed in NSW during the next decade, including:

- **HumeLink:** A 500 kV transmission upgrade connecting Project EnergyConnect and the Snowy Mountains Hydroelectric Scheme to Bannaby;
- **Sydney Ring:** A high capacity 500 kV transmission network to reinforce supply to Sydney, Newcastle and Wollongong load centres;
- **VNI West:** A new high capacity 500 kV double-circuit transmission line to connect Western Renewables Link (north of Ballarat) with Project EnergyConnect at Dinawan via Kerang;

- **New England REZ Transmission Link:** Transmission network augmentations defined in the NSW Electricity Strategy;
- **Hunter-Central Coast REZ Network Infrastructure Project:** Substation upgrades to supply generation from the Hunter and Central Coast to Sydney, Newcastle and Wollongong load centres;
- **Sydney Ring South:** A switching station and modular power flow controllers to reinforce supply to Sydney, Newcastle and Wollongong load centres; and
- **Queensland – New South Wales Interconnector (QNI Connect):** An ISP project to add capacity between southern Queensland and New England, following development of the New England REZ Network Infrastructure project.

These projects are in addition to existing transmission projects in development or under construction in NSW including Project EnergyConnect and the Central-West Orana REZ Network Infrastructure Project.

Each of these major projects will have complex interactions with the existing transmission network, including the need for prolonged outages to facilitate construction, connection and commissioning. The power system will have lower levels of resilience and redundancy during outages, and extensive planning and analysis will be required to ensure that adequate levels of system reliability and security can be maintained throughout, including during contingencies.

The cumulative effect of the increase in power system complexity and the increased interaction between projects will be an increase in the level of operational risk on the power system, and a step-change in the volume of analysis and decision-making needed to effectively plan, operate and manage the transmission system within Transgrid's obligations under Chapters 4 and 5 of the NER.

An uplift in control room and corporate office planning capabilities to improve decision-making across the longer-term planning horizon will enable the identification of the optimal operation of the network. In the absence of this capability, Transgrid will likely need to impose constraints on the system more frequently, including during planned outages to connect new network infrastructure, which is likely to curtail the operation of renewable generation in certain circumstances.

3. Potential credible options

This section describes the options we have investigated to date to address the identified need, including the scope of each option and the associated costs.

The AER considered that Transgrid's SSR operational tools project would need to explore a reasonable range of options to demonstrate the project is prudent and efficient under the expenditure objectives and criteria in the NER.[36] Transgrid has undertaken early works to further investigate and develop the options for improving our control systems and corporate office capabilities. This has involved both extensive investigation and planning by our internal teams, as well as the commissioning of expert input from independent international and Australian experts. These early works have allowed us to scope alternative options for meeting the identified need in this RIT-T.

In particular, we engaged external experts the Electric Power Research Institute (EPRI) and GHD Advisory to independently assess Transgrid's control room and operational planning capabilities against future operational needs and international best practice. Our options specification and scoping process has been informed substantively by the advice provided by these external experts. Transgrid intends to publish these reports once they are finalised as part of the Project Assessment Draft Review (PADR) submission.

We have also commenced engagement with the Transgrid Advisory Council (TAC) on the need for the investment and our approach to developing options. The dedicated focus sessions to date have outlined the drivers for investment, collaborated on addressing prior and current feedback and the approach to submitting the CPA.

At this early stage in the RIT-T process, we have identified three feasible options from a technical, commercial, and project delivery perspective that can be implemented in sufficient time to meet the identified need, ie:

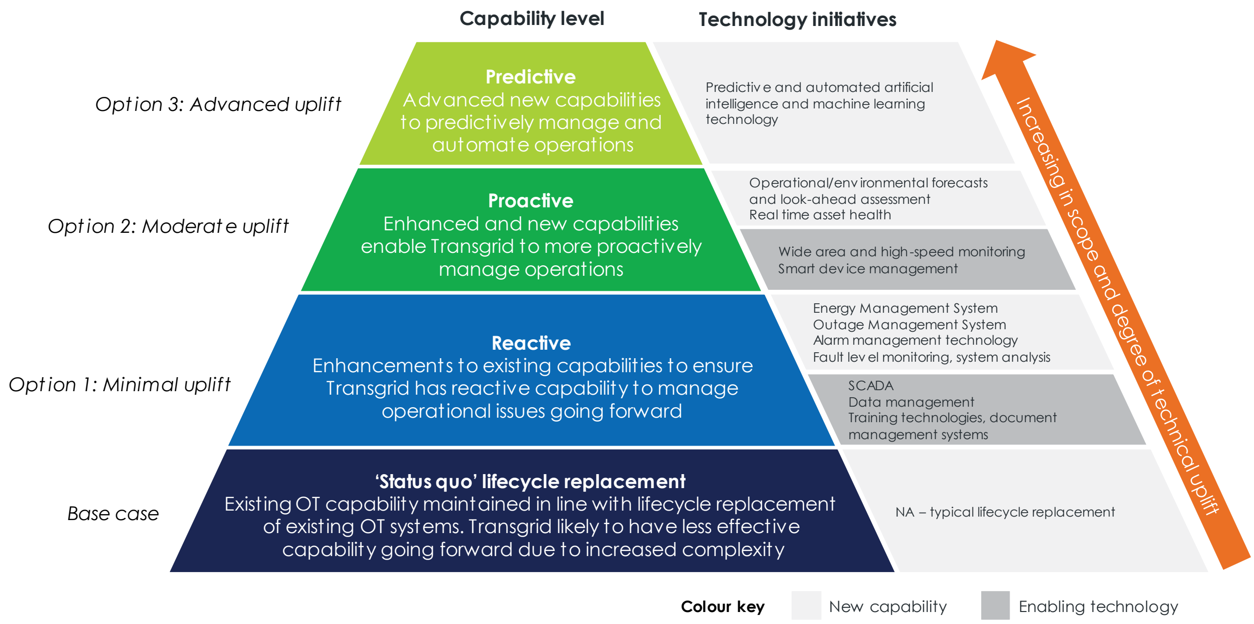
- Option 1: **Reactive capability -** provides enhancements to Transgrid's existing core OT capabilities to improve the reactive capabilities of Transgrid's control room and corporate offices;
- Option 2: **Proactive capability -** provides further, moderate enhancements across a portfolio of Transgrid's existing OT capabilities, as well as additional new capabilities, so that Transgrid can proactively plan for, and respond to, operational issues across its control room and corporate offices; and
- Option 3: **Predictive capability** - provides a suite of advanced enhancements to existing capabilities, as well as adding advanced new capabilities, to enable Transgrid to employ a predictive approach to operations in our control room and corporate offices.

Each option comprises and builds upon the preceding option, ie, Option 2 includes the initiatives and capabilities in Option 1, typically at a higher level of technical uplift. In other words, the options increase in scope, capability and the degree of technical uplift. For instance, while enhancements to data management and network modelling systems feature across all three options, the technical capability of this solution is highest under Option 3 (where technologies are integrated across more systems and reflect a higher degree of technical sophistication). The implementation of technology initiatives under each option have also been staged to prioritise the initiatives required most urgently to meet the needs of an evolving power system.

[36] AER, *Transgrid transmission determination – 1 July 2023 to 30 June 2028 – Attachment 5: Capital expenditure*, Final decision, p. 27.

Figure 3-1 summarises the key characteristics of the three options, in terms of the capabilities, associated technology and the extent of technical uplift.

Figure 3-1: Option capability-technology pyramid for operational tools



Note: In addition to the technology initiatives identified above, operational planning sits across several of the technology initiatives as an enabling and complementary function.

Each of the three options has been developed as a package to reflect the minimum incremental technology solution required to enable a defined level of capability (ie, reactive, proactive, predictive).

For example, under Option 1 the alarm management technology and energy management system (EMS) rely on data and functionality from the enhanced SCADA system to function effectively. Modern alarm management and EMS technologies are available in the latest versions of Transgrid's SCADA product, that utilise SCADA data to monitor the network in real-time to support greater situational awareness and swift decision-making, to minimise outage duration and customer impact. Likewise, the EMS relies on the enhanced SCADA data to maintain system stability and optimise power flows. As a result, partial implementation of an option would not result in the intended capability being achieved.

In addition to increasing scope, the options are increasing in the level of interaction and interdependency. For example, for the proposed data management system, Option 1 involves developing a data platform to reflect a 'single version of truth' to provide consistent data across Transgrid's control room and operational planning functions. Option 2 builds on Option 1 by enabling the proposed data platform to update automatically to reflect the current state of Transgrid's operational systems, e.g., Transgrid's enhanced SCADA system and energy management systems would be able to draw on data from Transgrid's asset management system.

The difference in the extent of technical uplift between options is presented in Figure 3-2 below which demonstrates that the options are increasing both in scope and technical maturity.

Figure 3-2: Difference in extent of technical uplift between options

Technology initiatives	Option 1	Option 2	Option 3
Data management and network modelling systems	△	○	●
EMS/SCADA system enhancement	△	○	●
Outage Management System and Switching Management	△	○	●
Real-time asset health monitoring system		○	●
Operational forecasts and look-ahead contingency assessment		○	●
Wide Area, High-Speed Monitoring		○	●
Smart transmission device management		○	●
Fault level and system parameter monitoring, power system analysis	△	○	●
Alarm management, visualisation and situational awareness enhancement	△	○	●
Training Technologies, Operational Documentation Management System and Operational planning	△	○	●

△ Minimal ○ Moderate ● Advanced

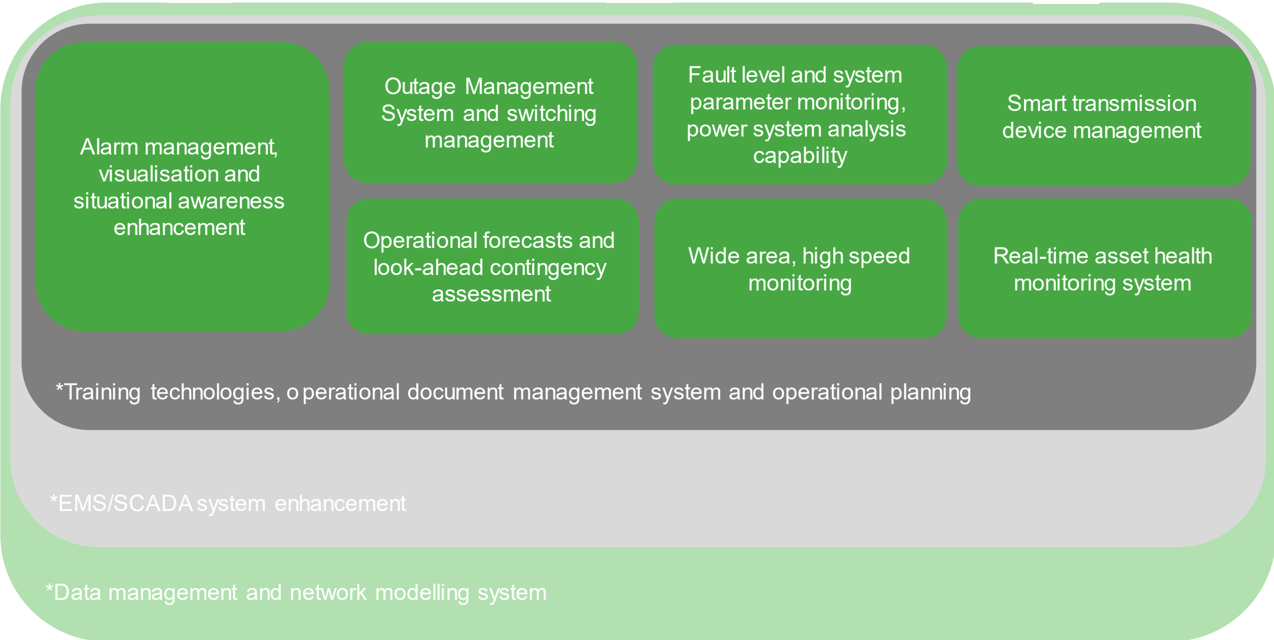
The figure demonstrates how, in general, Option 1 comprises upgrades to Transgrid's existing capabilities and OT tools, while Options 2 and 3 provide both enhanced and new capabilities, to differing levels of technical uplift.

We note that some of the technologies/tools being considered are 'enabling' for the purposes of operational capability, since they do not provide direct operational benefits in themselves but are necessary to realise the benefits of new capabilities. These enabling technologies include:

- Enhancements to SCADA systems, where that investment is a prerequisite to enabling other capabilities such as alarm visualisation or wide area, high speed monitoring (WAMS);
- Data management and network modelling systems;
- Training technologies and operational document management systems; and
- Operational planning functions.

Figure 3-3 presents a high level schema of the interactions and interdependencies between the investments in technology systems reflected in the options being considered in this RIT-T, and shows that enabling capabilities and systems are required to underpin the implementation of additional new capabilities. The figure also demonstrates that many of the capabilities and systems require a prerequisite enhancement to Transgrid's core SCADA and energy management systems (EMS).

Figure 3-3: Interaction between capabilities and 'enabling' technologies



Notes: * Enabling technologies

We are undertaking a market testing process (via issuing a Request For Information to selected vendors) to confirm the availability and costing of the proposed options being considered, and to test whether there are other credible options that should be considered in this RIT-T. We are also very mindful that our expenditure is efficient. In further refining the options we are also investigating the potential to achieve synergies with works being considered by AEMO and other Network Service Providers.

The results of this market testing and consideration of synergies will be considered in the analysis presented in the Project Assessment Draft Report (PADR).

We also considered two additional options that were not progressed for the reasons that are outlined in Table 3-7.

All costs presented in this PSCR are in 2024/25 dollars, unless otherwise stated.

3.1. Base case

Consistent with the RIT-T requirements, the assessment undertaken will compare the costs and benefits of each option to a base case. The base case is the (hypothetical) projected case if no action is taken, i.e.:[37]

> *"The base case is where the RIT-T proponent does not implement a credible option to meet the identified need, but rather continues its 'BAU activities'. 'BAU activities' are ongoing, economically prudent activities that occur in absence of a credible option being implemented."*

Under the base case, no proactive investment is taken to improve Transgrid's operational technology and tools for use in its control rooms and corporate offices. However, BAU activities such as life-cycle non-enhanced SCADA upgrade, and other regular OT refresh activities, as well as the hiring of additional personnel to manage some of the increase in control room and operational planning activities, will occur under the base case. Transgrid has received no capital allocation for a SCADA upgrade or related OT refresh activities within the current regulatory control period 2023-2028, and would seek lifecycle replacement funding in the next regulatory control period.

Importantly, the BAU investments reflected in the base case do not reflect the enhanced capabilities that are proposed under the options (including Option 1). As such, these BAU investments do not address the identified need for this RIT-T, and will not provide the benefits that are expected under the options considered in this RIT-T.

The cost of the BAU activities in the base case may be brought forward or avoided under the option cases. Transgrid currently has non-network approved revenue under the AER's regulatory determination for the 2024-28 period for some of the BAU investments reflected in the base case. This existing funding will be considered in identifying the additional revenue that Transgrid will require to implement the preferred option identified in this RIT-T, as part of our subsequent Contingent Project Application.

The base case reflects a higher risk that Transgrid may need to load shed during system normal conditions and contingency events, as human capability to respond to the increased complexity in the control room environment will be limited.

In addition, the base case is also expected to reflect higher fuel costs associated with NEM generator dispatch, as well as higher levels of greenhouse gas emissions associated with fossil-fuel generation, due to Transgrid having to manage its transmission network more conservatively in the future as system complexity increases, without the benefit of upgraded technology and tools in the regular operation and planning of network operations.

While this outcome is not one that Transgrid intends to encounter, and this RIT-T is being undertaken to avoid such a situation, it remains consistent with the RIT-T framework to assess the investment options against this 'do nothing' base case.

3.2. Option 1 – Reactive capability: uplift of core operational technologies and tools only

Option 1 – reactive capability, ensures that Transgrid can continue to respond to operational incidents and operational planning needs in a reactive capacity. This includes Transgrid's ability to effectively manage

[37] AER, *Regulatory investment test for transmission application guidelines – October 2023*, p 22.

control room operations and optimise operational planning (e.g., by optimising the duration of outages) in an increasingly complex operating environment.

Option 1 involves upgrades to several of Transgrid's core existing tools/systems that strengthen our reactive capability to respond to operational incidents and planning given an increasingly complex operating environment.

Specifically, Option 1 comprises upgrades and augmentations to existing systems, beyond the scope of the typical lifecycle replacement reflected in the base case (ie, the upgrades enable new functionality), including:

- **Outage Management System enhancements**: replacement of, and enhancement over and above, our existing outage management system to handle an increased number of outages and take account of a greater number of outage parameters;[38]
- **Alarm management, visualisation and situation awareness enhancements**: upgrades to reduce alarms levels and provide more informative alarms, thus reducing operators' cognitive load and enabling faster triage to improve monitoring of dynamic system conditions.; and
- **Fault level and system parameter monitoring and power system analysis**: deployment of EMS fault level and system parameter monitoring application to enable real-time identification of how close the system is to its operational limits. This will help define new technical operating envelopes and supporting secure operations, dynamic voltage control, and various operational support activities.

We have also identified that enhancements to our foundational capabilities are required to establish the base level of reactive capability required under Option 1. Specifically, enhancements to enable the capabilities expected from Option 1 include:

[38] We note that the expenditure proposed under this option represents an additional upgrade to our outage management system (ie, above that of lifecycle replacement), beyond expenditure accounted for in Transgrid's 2028-28 regulatory determination.

- **SCADA and Energy Management System enhancements**: upgrades over the lifecycle replacement of our energy management system and SCADA system capabilities to enhance SCADA front-end processors and provide modern SCADA/EMS functionality used for system modelling, contingency analysis, smart alarming and visualisation. These enhancements will as standard, provide a modern platform that enables integration with other external and internal system (i.e., the outage management system, network model management and the asset ratings team);
- **Data management and network modelling systems:** upgrades to our data management tools for transmission planning data, operational electrical network model data and asset ratings data, to provide a 'single version of truth' for power system modelling and network model management;
- **Training technologies and operational document management systems:** establishment of an advanced simulator-based training environment to upskill staff for a variety of scenarios under different power system conditions. In addition, an operational documentation management system will streamline access to information for network operators in control rooms, increasing the efficiency of operators in responding to control room incidents; and
- **Operational planning**: Software uplift and new roles for defining the technical limits applicable to the operation of the NSW network, managing risks to network integrity and operability associated with planned and unplanned network events and outages.

The scope of works for this option is expected to be carried out between 2025 and 2030, with the expected in-service date for the capabilities underpinned by this option being incrementally released until June 2030.

The estimated capital cost of this option is approximately $77.9 million.

Table 3-1 shows the expected capital expenditure by component.

Table 3-1: Breakdown of Option 1's expected capital cost, $m (+/- 25%)

Technology initiative	Capital cost
Outage management system and switching management	1.3
Alarm management, visualisation and situation awareness enhancement	9.4
Fault level and system parameter monitoring and power system analysis capability	3.8
EMS/SCADA system enhancements	35.7
Data management and network modelling system	13.0
Training technologies, operational document management system and operational planning systems	5.8
Early Works/CPA submission	8.9
Total capital cost	**77.9**

Table 3-2 shows the expected capital expenditure profile of this option.

Table 3-2: Annual breakdown of Option 1's expected capital cost, $m (+/- 25%)

	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30
Capital expenditure	9.2	11.9	17.1	17.1	17.1	5.5

The delivery of new operational tools and systems will necessitate a direct increase in full-time equivalent (FTE) headcount to ensure these tools deliver the required level of capability expected from Option 1. The increase in FTE is essential to facilitate the operation of these tools, as additional staff will be required to handle the new processes, provide training, and maintain the systems.

We have estimated this incremental increase in personnel to be roughly 11 FTEs. Total operating expenditure associated with Option 1 is estimated at $2.4m per annum (including FTE expenditure).

3.3. Option 2 – Proactive capability: uplift across a portfolio of operational technologies and tools, plus essential new capabilities

Option 2 – proactive capability, builds on Option 1 but involves a greater level and scope of technical upgrades across Transgrid's portfolio of operational technology and tools (rather than just Transgrid's core tools). In addition, Option 2 includes establishing new functionality to underpin proactive capabilities for Transgrid's control rooms operators and operational planners.

Transgrid expects that the initiatives delivered by Option 2 will among other things (in addition to the capabilities achieved under Option 1):

- facilitate more proactive monitoring of control room conditions and enhance situational awareness. In turn, these improvements will reduce the cognitive load on control room operators, and will support real-time decision making, to improve the outcomes from operational incidents as the system increases in complexity; and
- enable Transgrid's operational planners to optimise outage planning proactively, reducing the duration and scope of planned and unplanned outages, including during critical contingencies.

Specifically, Option 2 involves an uplift to capabilities across a portfolio of Transgrid's operational technologies and tools used in control rooms and corporate offices, plus the addition of new capabilities to address the increasing complexity of the power system.

Option 2 includes the same core technology upgrades as Option 1 but at a higher level of technical implementation. In addition, Option 2 includes several new technologies and tools which underpin the base 'proactive' capability required under Option 2. These new technologies/tools include:

- **Real-time asset health system:** systems to measure, monitor, and analyse asset technical envelope capabilities of assets in near real-time, to inform control room decision making;
- **Operational and environmental forecasts and impact assessment:** systems to provide early warnings and alarms to control room operators, asset monitoring and maintenance teams. Provides short term forecast decision support for contingency analysis to support network operation including voltage control, outage switching and emergency management;
- **Wide area, high speed monitoring (WAMS):** WAMS provides geospatial views of small signal oscillations and enables automated arming/dis-arming of special protection schemes based on system conditions; and

- **Smart transmission device management:** technical capability to increase the prevalence and effectiveness of Special Protection Schemes (SPS) which facilitate increasing levels of VRE.

We have also identified that data integration is required to establish the base level of proactive capability required under Option 2. Specifically, enhancements to enable the capabilities expected from Option 2 include:

- **Data management and network modelling systems:** integration of data from multiple sources across systems such as, real-time SCADA, operational electrical network model data, asset data and outage management systems to eliminate data silos, improve data accuracy and provide real-time insights to enable faster response time and/or more effective preparedness.

The scope of works for this option is expected to be carried out between 2025 and 2031, with the expected in-service date for the capabilities under this option being incrementally released until December 2031.

The estimated capital cost of this option is approximately $110.1 million.

Table 3-3 shows the expected capital expenditure by component.

Table 3-3: Breakdown of Option 2's expected capital cost, $m (+/- 25%)

Technology initiative	Capital cost
Outage management system and switching management	6.3
Alarm management, visualisation and situation awareness enhancement	12.1
Fault level and system parameter monitoring and power system analysis capability	6.2
EMS/SCADA system enhancements	38.7
Data management and network modelling system	16.0
Training technologies, operational document management system and operational planning systems	6.3
Real-time asset health monitoring system	7.7
Operational forecasts and look-ahead contingency assessment	5.7
Smart transmission device management	1.0
Wide area, high speed monitoring	1.2
Early Works/CPA submission	8.9
Total capital cost	**110.1**

Table 3-4 shows the expected capital expenditure profile of this option.

Table 3-4: Annual breakdown of Option 2's expected capital cost, $m (+/- 25%)

	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32
Capital expenditure	9.2	11.9	16.8	16.8	16.8	16.8	16.8	5.0

The delivery of new operational tools and systems will necessitate a direct increase in full-time equivalent (FTE) headcount to ensure these tools deliver the required level of capability expected from Option 2. The increase in FTE is essential to facilitate the operation of these tools, as additional staff will be required to handle the new processes, provide training, and maintain the systems.

We have estimated the incremental personnel requirement to be roughly 14 FTEs. Total operating expenditure associated with Option 2 is estimated at $4.2m per annum (including FTE expenditure).

3.4. Option 3 – Predictive capability: Advanced uplift to existing operational technologies and tools capabilities, and additional advanced new capabilities

Option 3 – Predictive capability, builds upon Option 2, but involves an advanced uplift across many of the technology systems to enable predictive and automated operations throughout key parts of Transgrid's operational control systems and operational planning technology stack.

Increased automation and predictive operation of our network is expected to enable operations closer to our technical envelope through the enablement of faster, automated decision-making and real-time decision support that would not be achievable using control room staff alone.

Specifically, in addition to the investments made under Option 2, Option 3 provides enhanced technical capability through adding:

- **Artificial intelligence (AI) and machine learning (ML) capabilities:** artificial intelligence and machine leaning in power system operation and control room functions to recommend network reconfiguration actions and generate plans for unplanned outages and load shedding events; and
- **Advanced wide area, high-speed monitoring (Advanced WAMS):** Enhancement to WAMS capabilities (over those considered in Option 2) to enable the EMS to ingest data from Renewable Energy Zones and DNSPs, facilitating linear state estimation down to the distribution network level. This supports the automated arming and disarming of SPS and the adjustment of control setpoints based on real-time system conditions.

Option 3 builds upon the technology initiatives outlined in Option 2 by providing automated and predictive capabilities by integrating WAMS data, artificial intelligence and machine learning into various processes. Compared to Option 2, Option 3 involves a greater level of technical capability across the following systems (see Figure 3-2):

- Data management and network modelling systems;
- Wide area, high speed monitoring;
- Fault level and system parameter modelling, and power system analysis;
- Alarm management, visualisation and situational awareness enhancements;
- Training technologies and operational document management systems; and
- Operational planning.

The scope of works for this option is expected to be carried out between 2025 and 2032 with the expected in-service date for the capabilities under this option being incrementally released until June 2032.

The estimated capital cost of this option is approximately $131.6 million.

Table 3-5 shows the expected capital expenditure by component.

Table 3-5: Breakdown of Option 3's expected capital cost, $m (+/- 25%)

Technology initiative	Capital cost
Outage management system and switching management	8.2
Alarm management, visualisation and situation awareness enhancement	14.0
Fault level and system parameter monitoring and power system analysis capability	6.7
EMS/SCADA system enhancements	40.7
Data management and network modelling system	19.5
Training technologies, operational document management system and operational planning systems	8.4
Real-time asset health monitoring system	10.2
Operational forecasts and look-ahead contingency assessment	10.7
Smart transmission device management	1.9
Wide area, high speed monitoring	2.4
Early Works/CPA submission	8.9
Total capital cost	**131.6**

Table 3-6 shows the expected capital expenditure profile of this option.

Table 3-6: Annual breakdown of Option 3's expected capital cost, $m (+/- 25%)

	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32
Capital expenditure	9.2	11.9	18.4	18.4	18.4	18.4	18.4	18.5

The delivery of new operational tools and systems will necessitate a direct increase in full-time equivalent (FTE) headcount to ensure these tools deliver the required level of capability expected from Option 3. The increase in FTE is essential to facilitate the operation of these tools, as additional staff will be required to handle the new processes, provide training, and maintain the systems.

We have estimated this incremental personnel increase to be roughly 14 FTEs. Total operating expenditure associated with Option 3 is estimated at $5.6m per annum (including FTE expenditure).

3.5. Options considered but not progressed

We considered two additional options to meet the identified need in this RIT-T. Table 3-7 summarises the reasons the following options were not progressed further.

We have not included non-network options in Table 3-7. We explain in section 4 below that non-network options are not expected to constitute potential credible options for this RIT-T, either on a standalone basis or as part of a potential credible option.

Table 3-7 Options considered but not progressed

Description	Reason(s) for not progressing
A significant uplift in staffing levels and training, without the introduction of new technology and tools.	This option is not considered viable. The near-exponential increases in data management, analysis and decision-making required over the next decade mean that system risks cannot be effectively managed with additional human resources alone. Furthermore, the skill sets required are specialised and are in high demand in the employment market, so it would be highly challenging to recruit, develop, train and retain staff in the numbers that would be required.
A fully automated technology solution that could be implemented without an uplift in human resourcing.	This option is considered non-credible because such tools are not available 'off the shelf' and it is unlikely that the solution could be fully developed and implemented within the timeframes required.

3.6. No material inter-network impact is expected

We have considered whether the credible options listed above is expected to have material inter-regional impact.[39] A 'material inter-network impact' is defined in the NER as:

> *"A material impact on another Transmission Network Service Provider's network, which impact may include (without limitation): (a) the imposition of power transfer constraints within another Transmission Network Service Provider's network; or (b) an adverse impact on the quality of supply in another Transmission Network Service Provider's network."*

AEMO's suggested screening test to indicate that a transmission augmentation has no material inter-network impact is that it satisfies the following:[40]

- a decrease in power transfer capability between transmission networks or in another TNSP's network of no more than the minimum of 3% of the maximum transfer capability and 50 MW;
- an increase in power transfer capability between transmission networks or in another TNSP's network of no more than the minimum of 3% of the maximum transfer capability and 50 MW;
- an increase in fault level by less than 10 MVA at any substation in another TNSP's network; and
- the investment does not involve either a series capacitor or modification in the vicinity of an existing series capacitor.

We note that each credible option satisfies these conditions. By reference to AEMO's screening criteria, there is no material inter-network impacts associated with any of the credible options considered.

[39] As per clause 5.16.4(b)(6)(ii) of the NER.

[40] Inter Regional Planning Committee, *Final determination: Criteria for assessing material inter-network impact of transmission augmentations*, 2004, pp 16-18.

4. Non-network options

We do not consider non-network options to be commercially and technically feasible to assist with meeting the identified need for this RIT-T.

Non-network options are unable to contribute towards meeting the identified need for this RIT-T, as non-network options cannot affect the capabilities of Transgrid's control rooms or corporate offices. There are currently no known non-network alternatives that could effectively augment or substitute for the investments that Transgrid is proposing.

5. Materiality of market benefits

This section outlines the categories of market benefits prescribed in the National Electricity Rules (NER) and whether they are considered to be material for this RIT-T.[41]

5.1. Changes in fuel consumption are expected to be material

Changes in fuel consumption arising through different patterns of generation dispatch are expected to be material, as Transgrid will have the ability to run the network less conservatively following this investment, as a result of:

- enhanced awareness and control capability in asset monitoring and grid operations to identify critical network issues and alert operators, reducing the risk that the network operates in an insecure state; and
- improved capacity to predict and manage network outages, including outages associated with the connection of new renewable generation, reducing need to operate our network conservatively to avoid EUE under a network outage.

As part of the PADR assessment, we propose to estimate the potential magnitude of avoided fuel consumption under each of the credible options, compared to the base case, on the basis of a case study approach using average dispatch cost data sourced from AEMO (rather than detailed wholesale market modelling). We consider this a proportionate approach to quantifying this benefit for this RIT-T.

5.2. Changes in Australia's greenhouse gas emissions are expected to be material

As a result of changes in fuel consumption arising through different patterns of generation dispatch, we expect changes in Australia's direct greenhouse gas emissions associated with NEM generation to also be material.

As part of the PADR assessment, we propose to estimate the value of avoided emissions under each of the credible options, compared to the base case, as part of the same case study approach. We will adopt the AER's Value of Emissions Reduction (VER) to quantify the value of avoided emissions.

5.3. Changes in involuntary load curtailment are expected to be material

Changes in involuntary load curtailment are likely to be material, as Transgrid is expected to have lower expected unserved energy (EUE) following this investment, relative to the base case.

As part of the PADR assessment, we propose to estimate the value of avoided EUE under each of the credible options, compared to the base case. This will include both planned and unplanned outages and will be valued using the AER's estimate of the Value of Customer Reliability (VCR). We will also have regard to the AER's final advice on the Value of Network Resilience (VNR),[42] and the extent to which some of the EUE risk relates to prolonged outages.

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[41] The NER requires that all classes of market benefits identified in relation to the RIT-T are included in the RIT-T assessment, unless the TNSP can demonstrate that a specific class (or classes) is unlikely to be material in relation to the RIT-T assessment for a specific option – NER clause 5.15A.2(b)(6). See Appendix A for requirements applicable to this document.

[42] AER, *Value of Network Resilience – draft decision*, 13 May 2024.

5.4. Wholesale electricity market benefits (outside of dispatch cost benefits) are not considered material

Other categories of market benefits arising from changes in the wholesale market outcomes are not considered material for this RIT-T at this stage (as outlined in the sections below). In particular, we do not expect the following classes of market benefits to be material for this RIT-T assessment:

- changes in voluntary load curtailment;
- changes in costs for parties other than the RIT-T proponent;
- changes in ancillary services costs;
- changes in network losses; and
- competition benefits.

5.5. No other classes of market benefits are considered material

In addition to the classes of market benefits discussed above, NER clause 5.15A.2(b)(4) requires that we consider the following classes of market benefits arising from each credible option. We consider that none of the classes of market benefits listed will be material for this RIT-T assessment for the reasons in Table 5-1.

Table 5-1 Reasons why other non-wholesale electricity market benefits are considered immaterial

Market benefits	Reason
Difference in the timing of unrelated expenditure	The investments in OT capabilities being considered in this RIT-T will not impact any other network investments Transgrid is currently considering to address other identified needs. As a consequence, this category of market benefit is not considered material for this RIT-T.
Option value	We note the AER's view is that option value is likely to arise where there is uncertainty regarding future outcomes, the information that is available is likely to change in the future, and the credible options considered by the TNSP are sufficiently flexible to respond to that change.[43] We note that the options considered in this RIT have the ability to be scaled up over time, so that future investment could increase the control room capabilities from, for example, those under Option 1 to those under Option 2 and then to those under Option 3 over time, as the scale of variable renewable energy integration and consumer energy resources in the NEM increases. The scenario analysis in the PADR will consider differences in the speed with which variable renewable energy investments and decentralised generation arise in the NEM going forward (based on the different ISP scenarios), and therefore the option value associated with options which are able to be scaled up in this manner. We do not consider that there will be additional option value associated with any of the options which is not captured under the scenario analysis.

[43] AER, *Regulatory Investment Test for Transmission – Application Guidelines*, October 2023, p. 57.

6. Overview of the assessment approach

This section outlines the approach that we propose to apply in assessing the net benefits associated with each of the credible options against the base case as part of the PADR.

6.1. Assessment period and discount rate

A 10-year assessment period from 2024/25 to 2033/34 is proposed to be adopted for this RIT-T analysis. This period takes into account the size, complexity and expected asset life of the options, which all involve OT assets.

Where the capital components of the credible options have asset lives extending beyond the end of the assessment period, the NPV modelling will include a terminal value to capture the remaining functional asset life. This ensures that the capital cost of long-lived options over the assessment period is appropriately captured, and that all options have their costs and benefits assessed over a consistent period, irrespective of option type, technology or serviceable asset life. The terminal values will be calculated as the undepreciated value of capital costs at the end of the analysis period.

A real, pre-tax discount rate of 7 per cent will be adopted as the central assumption for the NPV analysis presented in the PADR, consistent with AEMO's latest Input Assumptions and Scenarios Report (IASR).[44] The RIT-T requires that sensitivity testing be conducted on the discount rate and that the regulated weighted average cost of capital (WACC) be used as the lower bound. We propose to therefore test the sensitivity of the results to a lower bound discount rate of 3.63 per cent,[45] as well as an upper bound discount rate of 10.5 per cent (i.e., the upper bound in the latest IASR).[46]

6.2. Approach to estimating option costs

Transgrid will be undertaking further work (including drawing on a formal market engagement process) to refine the scope and cost estimates of the options prior to the PADR assessment.

At this stage, the cost estimate for the options presented in this PSCR has built upon the previous cost estimates developed for the SSR operational technology project, submitted with Transgrid's 2023-28 regulatory submission.

The SSR cost estimates were based on a bottom-up assessment of the labour, materials and expenses required for each option, taking into account the duration of work required. This bottom-up estimate was then adjusted in light of an independent 3rd party assessment, as well as to take into account a comparison with the cost of other similar projects.

The cost estimates for the options in this PSCR have taken the SSR cost estimates as a starting point and adjusted them to reflect differences in the scope of the options now being considered. In addition, all dollars have been escalated to 2024/25 dollars.

One of the key differences in the cost estimates in the PSCR compared to those in the SSR (and which has led to an increase in the cost estimates) is that the options allow for bringing forward a SCADA/EMS

44 AEMO, *2023 Inputs, Assumptions and Scenarios Report*, Final report, July 2023, p 123.
45 This is equal to WACC (pre-tax, real) in the latest final decision for a transmission business in the NEM (TasNetworks) as of the date of this analysis, see: AER, *TasNetworks – 2024-29 – Final decision – PTRM*, April 2024, WACC sheet.
46 AEMO, *2023 Inputs, Assumptions and Scenarios Report*, July 2023, Final Report, p. 123.

upgrade planned for the next regulatory period. This approach will leverage latest SCADA/EMS product functionality first to address the need, build on our existing asset, and optimise investments between the need for a SCADA/EMS lifecycle refresh early in the next regulatory period and the need for new functionality required for system operability.

Transgrid used the estimating tool MTWO to reflect 2024/25 labour rates based on actual outturn costs built up over more than 10 years (including labour quantities from recently completed projects). The MTWO estimating database is reviewed annually to reflect the latest outturn costs and to confirm that estimates are within their stated accuracy range and represent the most likely expected cost of delivery (P50). As part of the annual review, Transgrid benchmarks the outcomes against independent estimates provided by various engineering consultancies.

The cost estimates do not include or forecast any real cost escalation for materials.

Transgrid does not generally apply the Association for the Advancement of Cost Engineering (AACE) international cost estimate classification system to classify cost estimates. Doing so for this RIT-T would involve significant additional costs, which would not provide a corresponding increase in benefits compared with the use of MWTO estimates and so this has not been undertaken.

We estimate that actual costs will be within +/- 25 per cent of the central capital cost estimate. While we have not explicitly applied the AACE cost estimate classification system, we note that an accuracy of +/- 25 per cent for cost estimates is consistent with industry best practice and aligns with the accuracy range of a ‘Class 4’ estimate, as defined in the AACE.

Operating costs directly associated with the capital investment

Annual operating costs, where required to support and maintain proposed new technologies, are based on estimated labour rates from MTWO. The support model considers a blend of internal resourcing and external service providers. In addition to labour, the Original Equipment Manufacturer (OEM) hardware and software maintenance costs have been estimated based on a percentage of the purchase cost.

At this stage all technologies are assumed to be hosted on-premise to meet Transgrid’s highest security and data classification requirements. Consideration will be given to cloud-based technology solutions during the market engagement process, only where minimum security and data classification requirements can be achieved. Where cloud-based technologies form part of the solution, the Software as a Service (SaaS) OPEX will be shown in the PADR in accordance with NSW accounting guidance for capitalisation of Cloud-based software.

6.3. Three different scenarios will be modelled to address uncertainty

The RIT-T is focused on identifying the top ranked credible option in terms of expected net benefits. However, uncertainty exists in terms of estimating future inputs and variables (termed future ‘states of the world’).

To deal with this uncertainty, the NER requires that costs and market benefits for each credible option are estimated under reasonable scenarios and then weighted based on the likelihood of each scenario to determine a weighted (‘expected’) net benefit. It is this ‘expected’ net benefit that is used to rank credible options and identify the preferred option.

We currently expect that the credible options will be assessed under three scenarios as part of the PADR assessment, which differ in terms of the key drivers of the estimated net market benefits (i.e., future demand and renewable generation and storage growth, which leads to differing system complexities). Specifically, we will adopt different values for the demand growth rates and renewable generation and storage projections using the 2024 ISP step change, progressive change and green energy exports scenarios, which may affect the ranking of the credible options. We propose to weight the three scenarios on the basis of the ISP scenario weightings.

Table 5-6-1 Summary of scenarios

Variable / Scenario	Central	Low demand scenario	High demand cost scenario
ISP scenario (demand growth and renewable generation projections)	Step change	Progressive change	Green energy exports
Scenario weighting	*43%*	*42%*	*15%*
Discount rate	7.0%	7.0%	7.0%
Network capital costs	Base estimate	Base estimate	Base estimate
Operating costs	Base estimate	Base estimate	Base estimate

The effect of changes to other variables (including the discount rate and capital costs) on the NPV results will be investigated in sensitivity analysis as part of the PADR.

Appendix A Compliance checklist

This appendix sets out a checklist which demonstrates the compliance of this PSCR with the requirements of the National Electricity Rules version 216.

Rules clause	Summary of requirements	Relevant section
5.16.4 (b)	A RIT-T proponent must prepare a report (the project specification consultation report), which must include:	–
	(1) a description of the identified need;	2.1
	(2) the assumptions used in identifying the identified need (including, in the case of proposed reliability corrective action, why the RIT-T proponent considers reliability corrective action is necessary);	2.4
	(3) the technical characteristics of the identified need that a non-network option would be required to deliver, such as: (i) the size of load reduction of additional supply; (ii) location; and (iii) operating profile;	4
	(4) if applicable, reference to any discussion on the description of the identified need or the credible options in respect of that identified need in the most recent National Transmission Network Development Plan;	NA
	(5) a description of all credible options of which the RIT-T proponent is aware that address the identified need, which may include, without limitation, alterative transmission options, interconnectors, generation, demand side management, market network services or other network options;	3
	(6) for each credible option identified in accordance with subparagraph (5), information about: (i) the technical characteristics of the credible option; (ii) whether the credible option is reasonably likely to have a material inter-network impact; (iii) the classes of market benefits that the RIT-T proponent considers are likely not to be material in accordance with clause 5.15A.2(b)(6), together with reasons of why the RIT-T proponent considers that these classes of market benefit are not likely to be material; (iv) the estimated construction timetable and commissioning date; and (v) to the extent practicable, the total indicative capital and operating and maintenance costs.	3

In addition, the table below outlines a separate compliance checklist demonstrating compliance with the binding guidance in the latest AER RIT-T guidelines.

Guidelines section	Summary of the requirements	Section in the PSCR
3.5A.1	Where the estimated capital costs of the preferred option exceeds $100 million (as varied in accordance with a cost threshold determination), a RIT-T proponent must, in a RIT-T application: • outline the process it has applied, or intends to apply, to ensure that the estimated costs are accurate to the extent practicable having regard to the purpose of that stage of the RIT-T • for all credible options (including the preferred option), either > apply the cost estimate classification system published by the AACE, or > if it does not apply the AACE cost estimate classification system, identify the alternative cost estimation system or cost estimation arrangements it intends to apply, and provide reasons to explain why applying that alternative system or arrangements is more appropriate or suitable than applying the AACE cost estimate classification system in producing an accurate cost estimate	NA
3.5A.2	For each credible option, a RIT-T proponent must specify, to the extent practicable and in a manner which is fit for purpose for that stage of the RIT-T: • all key inputs and assumptions adopted in deriving the cost estimate • a breakdown of the main components of the cost estimate • the methodologies and processes applied in deriving the cost estimate (e.g. market testing, unit costs from recent projects, and engineering-based cost estimates) • the reasons in support of the key inputs and assumptions adopted and methodologies and processes applied • the level of any contingency allowance that have been included in the cost estimate, and the reasons for that level of contingency allowance	6.2
3.8.2	Where the estimated capital cost of the preferred option exceeds $100 million (as varied in accordance with an applicable cost threshold determination), a RIT-T proponent must undertake sensitivity analysis on all credible options, by varying one or more inputs and/or assumptions.	NA
3.9.4	If a contingency allowance is included in a cost estimate for a credible option, the RIT-T proponent must explain: • the reasons and basis for the contingency allowance, including the particular costs that the contingency allowance may relate to, and • how the level or quantum of the contingency allowance was determined.	NA