Transgrid

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System Security Roadmap Operational Technology Upgrades

RIT-T Project Assessment Conclusions Report

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Transgrid

Summary

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

The Australian Energy Regulator (AER) accepted the System Security Roadmap Operational Technology project as a contingent project for Transgrid's 2023-28 regulatory period, subject to the successful completion of early works and fulfillment of specific trigger events.[1]

One of the trigger events identified by the AER for the Contingent Project Application (CPA) is the successful completion of a RIT-T. This RIT-T demonstrates that an investment in operational technology and tools is the preferred option to address the increasingly complex operational challenges faced by Transgrid as the owner and operator of the New South Wales (NSW) and Australian Capital Territory (ACT) transmission network. Publication of this Project Assessment Conclusions Report (PACR) is the final step in the application of the RIT-T. It follows the publication of the Project Assessment Draft Report (PADR) on 12 May 2025.

The PADR received one submission, from the Justice and Equity Centre (JEC). Transgrid has engaged with JEC on the matters raised in its submission in preparing this PACR, to ensure that we understand their concerns. We have also refined the costs presented in the PADR, and the timing of some initiatives, through an independent assessment by DGA Consulting as well as further detailed planning by Transgrid's internal team. This has resulted in some minor changes in the costs and timing of the options since the PADR. The benefits have also changed slightly due to changes in timing of various initiatives. In addition, we have continued to engage with the Transgrid Advisory Council (TAC) in progressing and testing the assessment in this PACR.

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.

Control room operators must undertake a range of time-critical actions to maintain the network within a safe operating envelope, either ahead of or following a range of real-time events occurring on our network, Historically, the consistent profile and flexible output of baseload generators allowed transmission network operators to quickly stabilise the technical operating envelope of the power system and return the system to secure operations following contingency incidents (generator trips, equipment failures, weather events, etc.). However, the NSW power system is undergoing a transition from a small number of large, centrally distributed thermal generators to many small, distributed, variable generator connections and storage resources. This results in a more complex and dynamic transmission network to manage, given the significant increase in the number of resources connected to the transmission network, more monitored points for the control room, new asset types and variable bi-directional power flows. Further, as synchronous coal generation retires, the grid is losing the 'buffer' in the power system and will operate closer to the edge of the secure operating envelope. This means the power system could cascade faster in response to contingency events.

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

Whilst these developments will ultimately benefit consumers through increased access to lower cost, zero-emission energy sources 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, which is exacerbated by an increase in the number of transmission assets and the new types of transmission assets, combined 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 baseload 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, as a result of Transgrid maintaining static limits for inverters across the network in order to have sufficient confidence that the system will remain within its required operating envelope, these inverter limits will bind more frequently. This may limit the capacity of low marginal cost inverter-base renewable generation that can be utilised on the grid.
- there is an increased likelihood of emergency outages or disruptions when our operators are overburdened from needing to access and correlate information from multiple sources following contingency events, which are expected to increase in frequency. Specifically, there is a greater risk of failure for operators to take required actions within the required time, in turn leading to an increased risk of expected unserved energy (EUE) to end consumers going forward.

Transgrid plans to proactively address these potential adverse outcomes and this RIT-T is being carried out to provide Transgrid 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 identified need for this RIT-T is to increase overall net market benefits in the National Electricity Market (NEM) as the complexity of the electricity system increases, by:

- avoiding the need to impose static limits on the operation of inverter-based generators connected to our system going forward to ensure the system remains within its required operating envelope, and instead being able to utilise dynamic inverter limits reflecting real time conditions. This includes reducing the need to impose constraints during periods of planned and unplanned transmission outages, including outages necessary to connect new generation and undertake network upgrades; and
- allowing our control system operators to better prepare for, and then assess information and respond to, contingency events in an increasingly complex operating environment with a substantial increase in information sources needing to be monitored, which, amongst other things, is expected to reduce the likelihood of load shedding (i.e., EUE).

We expect market benefits will predominately arise from:

- reduced dispatch costs and greenhouse gas emissions, resulting from the ability to operate the system with fewer constraints on low marginal cost and low emissions renewable generation (through providing real-time fault levels and inverter limits); and
- reduced expected EUE, resulting from a reduction in the risk of contingency events escalating to the point where load shedding is required.

Our assessment indicates that the market benefits from enhancing the capabilities of the operational technology and tools (including our Advanced Energy Management System (AEMS) and Supervisory Control and Data Acquisition (SCADA) system) in our control room and corporate offices will 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).

Developments since the publication of the PADR

There have been a number of important developments since the publication of the PADR.

- We have obtained an independent cost review by DGA Consulting, as well as undertaken further, detailed internal planning. This resulted in a number of refinements to the costs and implementation timings of the various initiatives included in each of the options. Benefits have also changed slightly due to changes in implementation timing.
- Overall, the initial costs of both options has been subject to some minor changes since the PADR, and the costs associated with the refresh of technologies later in the assessment period (when the initial investment has reached end-of-life) has reduced, reflecting reduced effort on data cleansing and configuration in refresh projects compared with the initial implementation.
- We have also obtained an additional independent technical verification from the Electric Power Research Institute (EPRI), that the control room investments we are proposing under Option 2 are judicious and align with EPRI's recommendations and their experience of global power system developments.
- EPRI highlights that Option 1 has basic capability uplift but has in-built constraints. The limitations in scope and investment under Option 1 would almost certainly require inefficiently adding additional piecemeal investment to address gaps in operability in the medium term.
- Lastly, the Australian Energy Market Operator (AEMO) has provided a letter of confirmation supporting the preferred option in this PACR, which we are publishing on our website alongside this PACR. This letter reconfirms the importance and urgency for investment in Operational Technologies by NSPs and that the Option 2 investments by Transgrid are complementary to AEMO's investments.
- AEMO and Transgrid have validated alignment of our respective technology roadmaps, which is a key prerequisite to realising the benefits estimated by Transgrid in this RIT-T assessment.

We have continued to adopt AEMO's 2023 Input, Assumptions and Scenarios Report (IASR) and the 2024 Integrated System Plan (ISP) for the benefit quantification in this PACR, as reflecting the most up to date, consistent set of assumptions at the time that the assessment was undertaken. We note that AEMO's final 2025 IASR was published on 31 July 2025. We have undertaken a high-level comparison with the IASR inputs used in our quantification, and found that the changes are unlikely to materially affect our benefit calculations and therefore the outcome of this RIT-T.

Community engagement and social licence considerations are not expected to be relevant to this project since the investments proposed will take place in Transgrid's control rooms and corporate offices. Accordingly, no specific community is expected to be affected by the proposed investments.

Submission received in response to the PADR

Transgrid received one submission in response to the PADR, from the Justice and Equity Centre (JEC).

The JEC expressed concern that, whilst Transgrid has articulated why changes in the energy system have caused an increase in complexity of operations, Transgrid has not established a particular threshold to demonstrate that this increasing complexity requires extra investment to manage and cannot be acceptably managed with increased operating expenditure.

Transgrid's view is that there would be substantial, practical difficulties involved in quantifying operational complexity thresholds, and there are currently no established industry methodologies to draw on. As a consequence, we have not adopted a 'complexity threshold' approach as suggested by JEC. However, we have endeavoured to ensure that our case study assessment is as transparent as possible, including through highlighting the extent of constraints that may be imposed to address system complexity concerns in the absence of the investment. We have also provided further substantiation for our conclusion that hiring additional staff cannot substitute for operational tools in grid management, including that personnel cannot substitute for certain tool capabilities (e.g., real-time visibility and advanced alarm management).

We also note that evaluating investments in relation to the threshold is generally more applicable for reliability corrective action RIT-Ts (where there is often a threshold set out in an obligation on Transgrid, which cannot be breached), rather than for market benefit RIT-Ts.

JEC also considered that, to the degree that the need to invest can be established, Option 1 would be preferable as it would ensure 'minimum standards are met at least cost' and would therefore minimise the risk that consumers will bear unnecessary excess costs, whilst not precluding Transgrid's operational capabilities being further uplifted if needed in future.

Transgrid has obtained further independent technical verification from EPRI. EPRI highlights that Option 1 would not maximise the net economic benefit resulting from fully mitigating the potential reliability risks driven by likely growth patterns, and would require further investment in the short-medium term, duplicating expenditure and introducing uncertainty and delays.

Further, AEMO has provided its support for Option 2, as representing capabilities that are required now, and are complementary to the operability initiatives AEMO is also progressing.[2]

In line with the RIT-T requirements, Transgrid has continued to identify the preferred option under this RIT-T as the option that has the greatest expected net economic benefit, which is Option 2.

Two credible options have been assessed in the PACR

Transgrid has investigated and considered 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 (EPRI and GHD Advisory). It has also been informed and refined through a comprehensive market testing process, centred on a Request for Information (RFI) process conducted ahead of the PADR.

We have identified two credible options from a technical, commercial, and project delivery perspective, i.e.:

[2] *AEMO, Update support for Transgrid's proposed investment to upgrade operational technology and tools for use in its control room and corporate offices*, 15 September 2025.

- Option 1: **Reactive capability –** provides enhancements to Transgrid's existing core operational technology and tools to improve the reactive capabilities of Transgrid's control room and corporate offices; and
- Option 2: **Proactive capability –** provides further, moderate enhancements to Transgrid's existing operational technology and tools, in addition to several new capabilities, so that Transgrid can proactively plan for, and respond to, operational issues across its control room and corporate offices.

Option 2 includes the initiatives and capabilities in Option 1, typically at a higher level of technical uplift. In other words, Option 2 increases in scope, capability and the degree of technical uplift for each of these capabilities. The implementation of technology initiatives under each option is staged to prioritise initiatives that deliver the highest immediate net benefits, and defer investments that can be implemented in the future. Option 2 includes initiatives out to 2030, but does not also include longer-term initiatives which may be added in future.

The two options have been developed as packages to reflect the minimum incremental technology solution required to enable a defined level of capability (i.e., reactive or proactive). As a result, partial implementation of either option would not result in the intended capability uplift under each option being achieved, and so would not provide the benefits of avoided unserved energy, fuel costs and greenhouse gas emissions identified.

The scope and timing of these two options was tested and refined in the light of responses to the RFI. Since the PADR, the options have been subject to additional independent assessment by DGA Consulting and further planning by the internal Transgrid team. This has led to some changes in the assumed implementation timing for initiatives, as well as to minor scope refinements to both options – we discuss this further in this PACR.

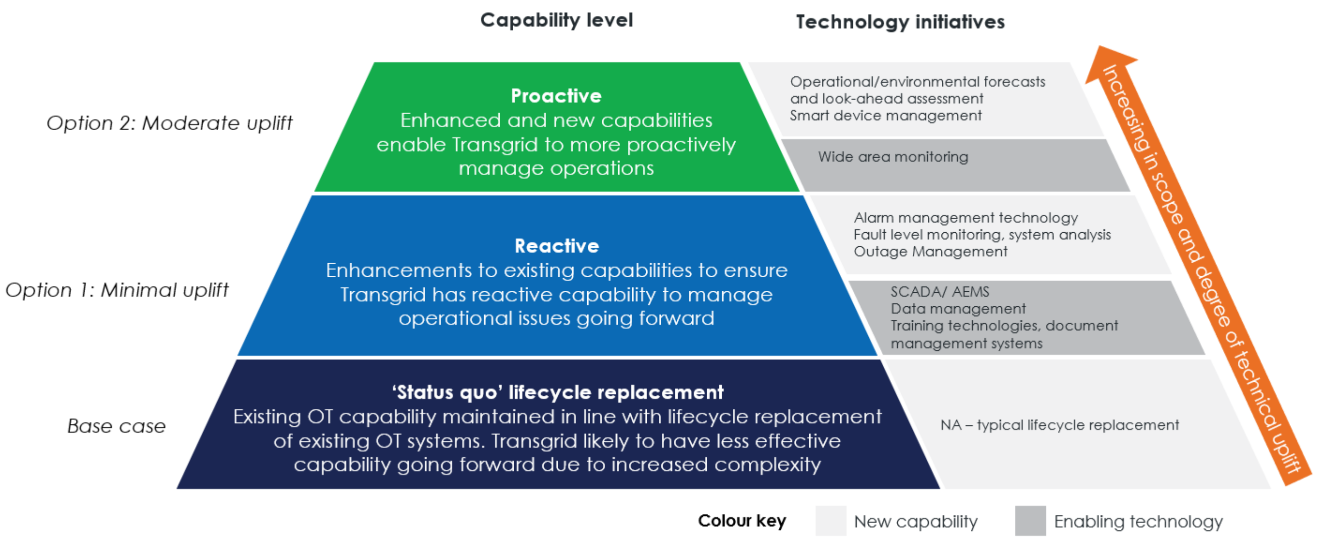
In the PSCR, we also identified a third option, i.e., Option 3: **Predictive capability** – this option would have provided a suite of advanced enhancements to existing capabilities, as well as adding advanced new capabilities, to enable Transgrid to employ a predictive approach to operations in our control room and corporate offices. Option 3 would provide a degree of future-proofing for longer-term functionalities which are expected to be required. However, in responses to the RFI, vendors indicated that the desired levels of capability uplift within Option 3:

- whilst well aligned with industry and software product roadmaps, had high degrees of cost and functional uncertainty;
- had significantly higher costs (i.e., more than triple) compared to Transgrid's preliminary estimates in the PSCR and compared to the cost escalation for the other options between the PSCR and PADR; and
- could not be delivered in a similar timeframe to Option 2 (i.e., would take significantly longer to deliver).

Accordingly, Transgrid does not currently consider Option 3 technically and commercially feasible, and it has not been assessed in the PADR or this PACR. However, because each option builds upon the previous option, the proposed technology architecture for Options 1 and 2 will still enable Transgrid to readily scale and take advantage of new functionality sought within Option 3 at a future date, if there are net market benefits in doing so.

The differing features of the two credible options are illustrated in Figure E-1.1 below, which summarises the key characteristics of the options, in terms of the capabilities, associated technology and the extent of technical uplift.

Figure E.1.1: 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.

We present the estimated capital expenditure for upgrades to our operational technologies and tools under each option in Table E.1 below. This capital expenditure reflects a 6.8 per cent decrease compared to the PADR for Option 2, and a 0.3 per cent decrease for Option 1, resulting from a range of scope and cost refinements following the independent assessment by DGA Consulting and further planning by Transgrid – discussed further in the PACR. DGA supports Transgrid's revised capex estimates as representing an efficient level of costs to deliver the scope of the proposed capability.[3]

Table E.1 Summary of estimated capital expenditure ($m $2024/25).

	Estimated capital expenditure
Option 1	122.7
Option 2	167.1

As Transgrid is undertaking this RIT-T over a 15-year assessment period, to capture the full benefit realisation period for operational technologies and tools which reach the end of their economic life prior to the end of the period, we have included indicative refresh costs in both the base case and option cases. For the purposes of this PACR, Transgrid has generally assumed the indicative replacement costs in real terms are 20 per cent less than the initial costs at the end of the economic life of the assets. This discount (which was not applied in the PADR assessment), reflects the independent advice received from DGA Consulting that a like-for-like refresh is likely to be less expensive than a new build, given the learnings and

[3] DGA Consulting, *Independent Review of System Security Operability Costs – Option 2*, 30 September 2025, version 1.2, p 6 and DGA Consulting, *Independent Review of System Security Operability Costs – Option 1*, 30 September 2025, version 1.2, p 6.

labour cost saving opportunities compared to the original build.[4] We continue to believe that our approach reflects a conservatively high estimate of the refresh costs. This is consistent with DGA Consulting's finding that there is potential for some refresh costs to be less than 80 per cent of original costs.[5]

We considered five additional options, including the potential for non-network options, to meet the identified need during the course of this RIT-T. However, these options were not progressed as they were not considered to be commercially and technically feasible to assist with meeting the identified need for this RIT-T (discussed further in the PACR).

Both options are expected to deliver significant economic benefits

Upgrades to Transgrid's operational tools represent a step change in control room capabilities, which is expected to provide a broad range of benefits that accrue to consumers.

The market benefits of operational technologies and tools are not typically quantified through the RIT-T process, and are difficult to measure. This is because, unlike the benefits from specific network augmentation or network replacement expenditure (which are the most typical investments subject to the RIT-T) which have a specific, traceable impact on electricity network operation, the benefits from operational technologies and tools accrue across the network through improved system reliability, market efficiency and utilisation.

Accordingly, the approach to quantifying the benefits from operational technologies and tools needs to be different to that taken for network investments. We have adopted a 'case study' approach to estimate a subset of the market benefits from each option compared to the base case to showcase the improved operational capability benefits from specific operational technologies and tools.

The case study approach is a transparent and tractable method of quantifying the market benefits from upgrades to Transgrid's operational tools. The case studies link technology upgrades to specific, distinct outcomes and market benefits that result from that uplift in operational capabilities. Rather than attempt a broad calculation of all possible benefits, we've focused on three specific case studies where we can make transparent assumptions about the change in outcomes that we expect to be achieved under each option, and have estimated the benefits associated with these case studies.

Our case study approach represents a conservative approach to quantifying the market benefits, as we:

- only quantify a subset of the total market benefits that are likely to accrue from this project, focusing on case studies that result in market benefits that can be estimated simply and tractably using a set of transparent assumptions; and
- have made reasonable assumptions where there is uncertainty to ensure that we have not overestimated the benefits of these investments.

Whilst the full range of benefits associated with the options is difficult to measure in dollars, the options are expected to create real value through improved operations, enhanced staff capabilities and their contribution to meeting regulatory requirements.

4 The exception is the refresh costs of the incremental facilities associated with the SCADA/AEMS system, where we continue to assume that future refresh costs remain the same in real terms.

5 DGA Consulting, *Independent Review of System Security Operability Costs – Option 2*, 30 September 2025, version 1.2, p 6 and DGA Consulting, *Independent Review of System Security Operability Costs – Option 1*, 30 September 2025, version 1.2, p 6.

We have estimated benefits under three case studies, which are summarised in Table E.2.

Table E.2: Summary of market benefit case studies estimated in this RIT-T

ID	Case study	Benefit driver
Case study 1	Reduction in the likelihood of unserved energy	Early detection and intervention for faults reduces the probability of an event escalating to an outage event with unserved energy, as well as the need to operate the network more conservatively and take assets offline. This outcome arises from better visibility of asset conditions and network fault levels, prioritisation of information and supported decision making, which together reduces the cognitive load on control room operators in a complex operating environment. This RIT-T only quantifies the benefits related to the reduction in the likelihood of unserved energy and does not quantify any additional benefits from reduced risk of asset failure or less conservative network operation.
Case study 2	Increase in network utilisation	Alleviating pre-emptive and conservative static limits on inverter-based generation, through real-time and near-term network analysis replacing static scenario measurements. This facilitates less conservative network asset utilisation by enabling dynamically changing inverter limits and providing the ability to operate closer to the power system's technical envelope.
Case study 3	Reduction in the duration of outages	Reduction in planned outage duration associated with switching operations through automation of planned generator inverter changes.

We have estimated the gross market benefit for each option under each case study for each of the 2024 ISP scenarios. Table E.3 below presents the present value of the gross market benefits for each option under each case study, and in total, on a weighted basis across the three ISP scenarios. This shows that significant benefits for Option 2 are delivered under all three case studies, and in particular that the additional technologies enabling increased network utilisation under Option 2 deliver substantial additional benefits compared to Option 1.

Table E.3: Present value of gross market benefits by case study ($m, PV)

Case study	Option 1	Option 2
Reduction in the likelihood of outages	103.5	160.5
Increased network utilisation	10.9	61.5
Reduced duration of switching operations	74.8	74.8
Total	189.3	296.8

The net present value analysis confirms Option 2 as the preferred option

The present value of estimated costs for each option are summarised in Table E.4 below. We have assessed the options against a base case where no investment to improve Transgrid's operational technology and tools for use in its control rooms and corporate offices is undertaken. However, consistent with the base case under the RIT-T, we assume a range of economically prudent Business As Usual (BAU) activities to best maintain our control room capabilities required for compliance with the National Electricity Rules (NER) until the end of the assessment period will occur, including a lifecycle, non-enhanced replacement of our SCADA/AEMS system by June 2031. Because we have undertaken a 15-year assessment for this RIT-T to capture the full benefit realisation period, these options include refresh costs where required for technologies to 2039.

Table E.4: Present value of capital and operating costs by option (present value, $ millions)

	Capital costs	Operating costs	Total costs
Option 1	104.1	33.1	137.2
Option 2	133.8	44.2	177.9

In Table E.5 below, we set out the net present value (NPV) for each option across the three scenarios modelled, and on a weighted basis. The analysis shows that both options are expected to deliver net benefits across all three ISP scenarios. On a weighted basis, Option 2 is expected to deliver a NPV of $118.9 million, compared with $52.0 million for Option 1.

Table E.5: Net present value of options compared to base case (present value, $ millions)

	Progressive change	Step change	Green energy exports	Weighted NPV	Rank
Option 1	40.0	47.9	97.8	52.0	2
Option 2	73.6	135.5	198.1	118.9	1

We have also undertaken sensitivity testing to examine how the net economic benefit of the credible options changes with respect to changes in key assumptions, including changes to costs, the total amount of benefits realised, and the discount rate. The results of the sensitivity analysis show that no reasonable change in key assumptions would result in Option 2 no longer being the preferred option or failing to deliver positive net market benefits over the evaluation period. We also find that a 1 year delay in the delivery of the preferred option (Option 2) would result in a $6.5 million decrease in net market benefits.[6]

Given the above and consistent with the findings of the PADR, Option 2 is confirmed as the preferred option for this RIT-T as it is the credible option that maximises the NPV of the net economic benefit (in accordance with NER clause 5.15A.2(b)(12)).

Next steps

This PACR represents the final step of the consultation process in relation to the application of the RIT-T process undertaken by Transgrid.

Parties wishing to lodge a dispute notice with the AER may do so prior fto 7 November 2025 (30 days after publication of this PACR). Any dispute notices raised during this period will be addressed by the AER.

Following completion of this RIT-T, and the written support received from AEMO, Transgrid now intends to submit a CPA to the AER so that we are able to progress with this key investment.

6 We discuss this in further detail in section 7.4.