January 2026

Powerlink 2027-32 Revenue Proposal

Appendix 4.08

Future Grid Operations Technology Investment Plan

Contents

Executive Summary

Over the next five years, Powerlink will face significant challenges due to the shifting nature of grid operations, and evolving consumer, regulatory and industry expectations for Transmission Network Service Providers (TNSPs). The increased integration of renewables and storage devices to the network is deepening operating complexity and with it the increased risk of generation curtailment, operational inefficiencies and power outages. Investment is required to improve grid visualisation and monitoring capabilities, uplift resilience against system events, respond to an increased volume of alarms, and make informed real-time data driven decisions.

Powerlink developed its Future Grid Operations (FGO) Strategy in 2024 to help deliver safe, reliable, and affordable energy during Queensland's transition to a low-emissions future. Five strategic shifts have been identified to respond to emerging operational challenges and underpin the Strategy, including:

- **Expanded operating lens and control**
- **Proactive but selective market influence**
- **Customer focused operations**
- **Innovative and automated operations**
- **'Operate Big' culture**

At the same time, Powerlink is subject to several challenges and trends that are impacting its future operating environment, including the rapid growth of renewables, increased generation decentralisation and regulatory reforms responding to the complex and evolving nature of consumer electricity needs. This is being further underpinned by internal and external factors which is changing the role of TNSPs.

To support the strategic shifts under the FGO Strategy, a Future Grid Operations Technology (FGOT) Investment Case has been developed with three investment streams:

1. **Forecasting and data support** (with total capital expenditure of $23.6m): Enhancing short-term forecasting for load, generation, and weather to improve network resilience and operational planning
2. **Decision Support** (with total capital expenditure of $44.4m): Developing integrated tools to improve control room decision-making, situational awareness, and operational safety
3. **Wide Area Monitoring Protection and Control (WAMPAC)** (with total capital expenditure of $12.3m): Upgrading protection systems with dynamic controls, wide-area visualisation tools, and integration of emerging grid technologies to get more out of the existing network

The total of the FGOT Preferred Option is summarised in Table 1 which provides a positive NPV.

Table 1 Total FGOT Capital expenditure ($m FY25/26)

	2027/28	2028/29	2029/30	2030/31	2031/32	Total
FGOT	9.4	16.5	17.0	17.9	19.4	**80.3**

Purpose and scope

Purpose

This document outlines the proposed Future Grid Operations Technology (FGOT) investments and serves to:

- Present the risks facing the transmission operational environment due to the evolving power system
- Present the strategic direction and investment that will guide future grid operations through to 2032 and beyond
- Detail Powerlink's FGOT investment streams and key initiatives that underpin Powerlink's proposed capability uplifts
- Describe the governance arrangements that have informed and will continue to oversee investment decisions in this area
- Set out the forecast capital expenditure.

Scope

The FGOT investments outlined in this document fall under the non-load related network capital expenditure category. The investments focus on the provision of systems, tools and data capabilities that enable Powerlink to operate the Queensland transmission network safely, efficiently, and securely, in the context of a rapidly evolving energy system. These investments are designed to support the operational requirements of a grid transitioning from traditional synchronous generation to one with an increasing share of asynchronous and distributed energy resources.

Document History

Date	Version	Comment
16 January 2025	1.0	Submission

Acronyms

AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AEMS	Advanced Energy Management System
AER	Australian Energy Regulator
AI	Artificial Intelligence
CRM	Customer Relationship Management
DER	Distributed Energy Resources
FGO	Future Grid Operations
FGOT	Future Grid Operations Technology
IMS	Incident Management System
NEM	National Electricity Market
OMS	Outage Management System
OT	Operational Technology
PMU	Phasor Measurement Unit
RIT-T	Regulatory Investment Test for Transmission
RPRG	Regulatory Proposal Reference Group
TNSP	Transmission Network Service Provider
WAMPAC	Wide Area Monitoring Protection and Control

Future Operational Environment

Challenges and trends impacting the future operating environment

The energy sector continues to face a dynamic and rapidly evolving environment shaped by various market forces and emerging factors.

The Australian power system is evolving from one dominant in large-scale synchronous thermal generation sources to a future with significant distributed, inverter-based variable generation and decentralised storage resources. This shift introduces complexity for control room operators as they are required to perform a range of time-critical actions to keep the system within a safe operating envelope, both in anticipation of and in response to real-time events on the network.

Traditionally, the consistent output and predictable operating patterns of thermal generators allowed transmission operators to optimise the network in real time, drawing on well-established and engineering validated operating modes developed from years of refinement – for example, a typical summer Monday demand and generation profile would correspond to a known network operating characteristic. This predictability also enabled operators to quickly restore the system to secure operation following contingencies such as generator trips, equipment failures, or severe weather, because the behaviour underpinning contingency plan was itself highly consistent.

Since 2017, Powerlink has delivered 34 connection projects, with 9 under construction and 103 more in the pipeline, driving Queensland's Energy Roadmap through a widely distributed network of variable generation and decentralised storage, as illustrated in Figure 1. The integration of these resources into the power system creates a more dynamic and complex environment for transmission control room operations through an increased numbers of connections and customers to interact with, greater number of network monitoring points, new asset classes and variable, bidirectional power flows. In this context, the consistency once inherent in generation dispatch patterns are now highly variable and weather dependent, challenging historical operational approaches that relied on predictable behaviour for simplification and optimisation. That foundational consistency simply no longer exists.

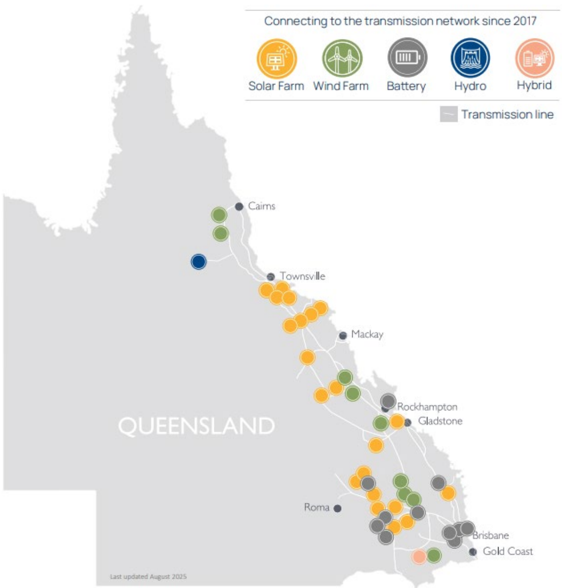

Figure 1 Existing and Committed Projects since 2017

Historically, although seasonal changes created some variation in demand and generation, overall patterns remained predictable enough to schedule outages of transmission elements with minimal customer or market impact. Today, however, significant daily and intraday variability has eroded this predictability, making it far more difficult to identify reliable, low risk outage windows, where engineering analysis must now account for a wider range of operating conditions

For example, flows on the Central Queensland to North Queensland transmission network historically followed relatively predictable seasonal patterns; today, they are significantly more variable and frequently bidirectional (Figure 2). Increased variability in power flows means network operations must shift from predictable, seasonal patterns to dynamic, real-time management. This complexity makes outage scheduling more challenging, as timing must account for fluctuating generation and bidirectional flows, potentially requiring rescheduling at short notice. Accurate forecasting becomes essential to anticipate these changes, optimise outage windows, and maintain system security and reliability while integrating variable renewables and storage.

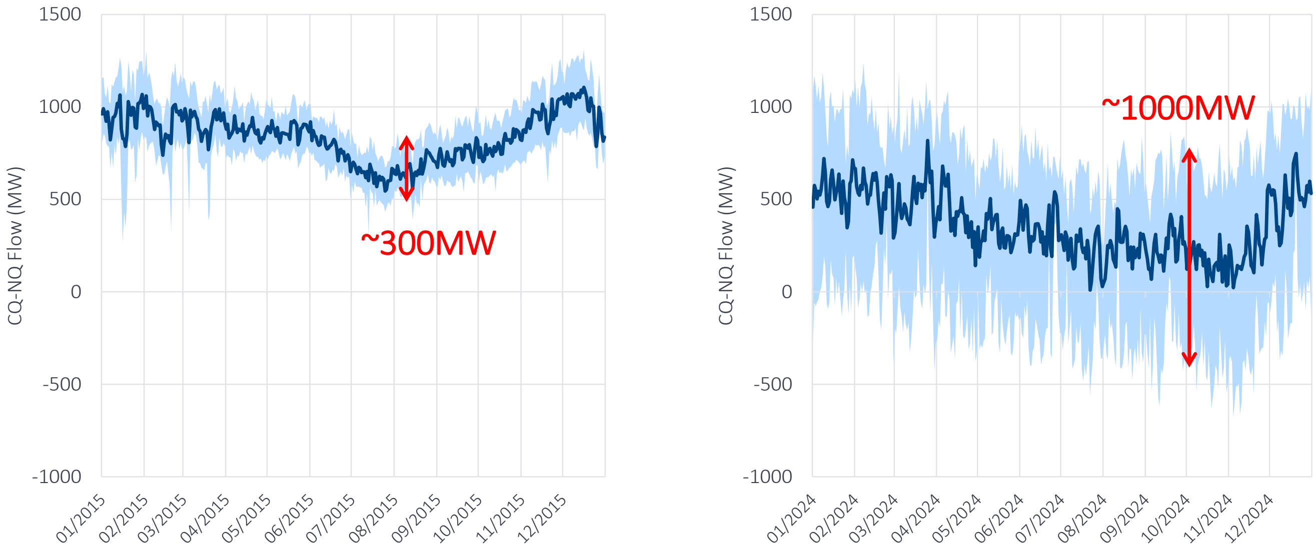

Figure 2 Increased variability in Central Queensland to North Queensland network flows (2015 versus 2024)

Queensland's power system has historically comprised of synchronous generation such as coal-fired power stations, gas turbines and hydro-electric plants which inherently provide various system security services, such as voltage regulation, inertia and system strength, as an inherent characteristic of their energy dispatch. These were either continuously operating plants or predictably scheduled peaking plants, meaning both their energy dispatch and their contribution to system security were stable, well understood and largely deterministic.

In contrast, the growing contribution of inverter-based generation sources, represents a fundamental shift: instead of a small fleet of predictable generators, the system now depends on large numbers of weather-dependent units that are dynamically and economically dispatched by the market. This shift prompts the need for new approaches to obtaining these services and tools to assist in operational decision making and validation on service provision. While this delivers economic efficiencies and supports decarbonisation, it also means that the security services once inherently provided by synchronous machines must now be actively procured, modelled and validated; processes that previously relied on a small number of predictable operating states. In today's environment, the wide range of possible combinations created by dynamic market dispatch and contract conditions requires far more sophisticated operational support, systems and tools to ensure these services are delivered securely and efficiently.

Modern inverter-based technologies use software-driven controls to emulate services such as inertia and system strength, but their performance depends on configuration, tuning and operating conditions. Misconfigurations or unexpected responses can trigger oscillations or instability that spread faster and less predictably than in synchronous systems. These technologies deliver lower-cost, low-emission energy, but they also introduce operational risks that legacy operational systems cannot manage. Operators now need visibility of dynamic behaviour, control settings, and how these resources interact with the network, as well as clear insight into when automated controls intervene and why. This requires more granular data, real-time situational awareness and advanced decision-support tools. International experience including analysis of the 2025 Iberian Peninsula blackout shows how limited visibility of inverter and Distributed Energy Resource (DER) behaviour can escalate disturbances, reinforcing the need for stronger monitoring and operator-facing transparency in increasingly inverter-dominated grids.

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The accelerating pace and complexity of these changes far exceed the operating environment of previous decades. Earlier approaches focused on optimising a small number of stable and well understood system behaviours. That era has passed. As the energy transition unfolds, operators will require modern tools, enhanced visibility and rapid decision support capabilities to detect emerging risks and respond effectively to threats to system reliability and security. These capabilities are essential to maintaining safe and reliable services for customers in a system whose operating paradigms are evolving continuously.

Current Operational Systems

A number of Powerlink's current operational systems are being replaced during the 2022–27 regulatory period to address end-of-life risk and establish a stable, contemporary platform for ongoing transmission system network operations. The new systems, including the Advanced Energy Management System (AEMS), scheduled for go-live in August 2027, introduces some incremental capability as expected from a contemporary system implementation, but their primary purpose is to restore the reliability and supportability of the core operational environment. The project is focussed on delivering foundational elements and core data alignment, owing to the architectural and interoperability complexity identified during detailed design. While modern Energy Management System platforms are essential foundations, vendors cannot keep pace with the full breadth of emerging network challenges within their base products, and it is now common for system operators to complement core systems with targeted, modular operational solutions that address specific risks as they arise. The proposed FGOT investment therefore seeks to leverage the foundation capability, data and stabilised platform being delivered in this period and incrementally develop the targeted operational tools needed to efficiently and effectively meet emerging challenges.

Future Grid Operations Strategy

The Future Grid Operations (FGO) Strategy was developed by Powerlink in 2024 to guide the organisation through the operational challenges of Queensland's energy transition to 2032 and beyond. It was initiated in response to structural shifts in the electricity system, including the rapid growth of large-scale weather-dependent generation, greater system variability, increased decentralisation of generation, and evolving customer and market expectations. These structural shifts demand significant changes in how Powerlink plans, operates, and invests in the transmission network to both support AEMO in maintaining system security and fulfil Powerlink's overarching obligations under the NER.

The FGO Strategy encompasses five strategic shifts representing deliberate choices made by Powerlink subject matter experts, key stakeholders, and executives to respond to the operational challenges of the energy transition. Each shift reflects a defined future-state operating objective and is underpinned by targeted initiatives designed to uplift capability maturity across systems, processes, and people—enabling Powerlink to deliver on its long-term operational ambition. The required operational capability uplifts and associated initiatives from the strategic shifts are shown in Figure 4 with Table 2 providing a description of each of the strategic shifts.

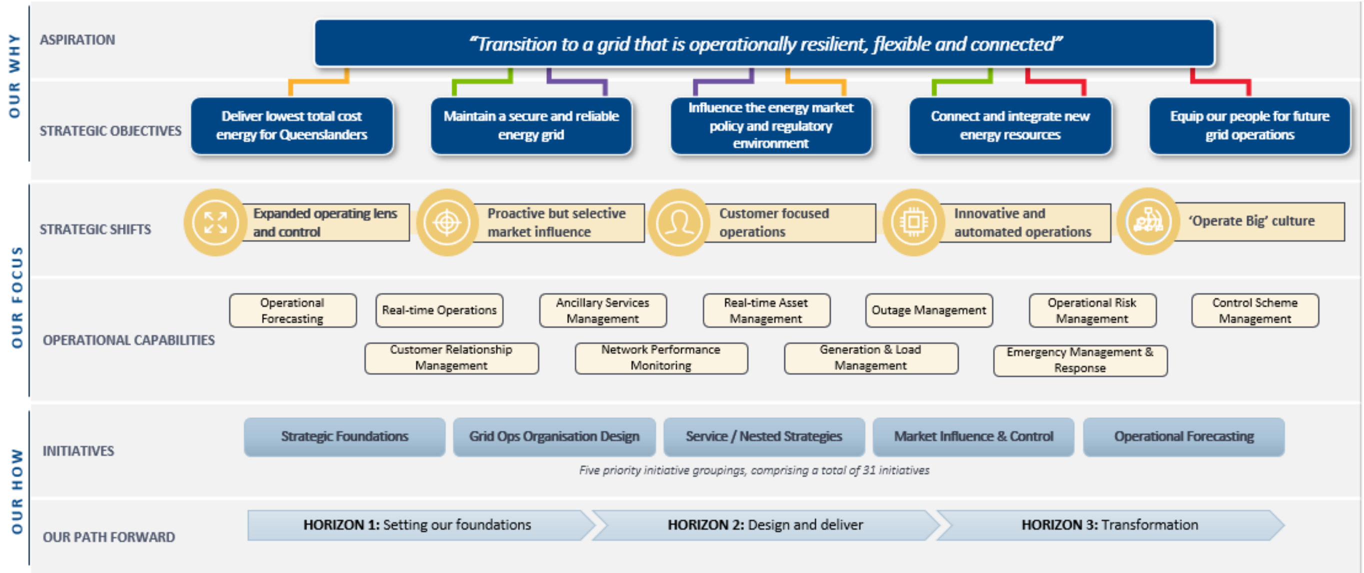

Figure 4 FGO Strategy Strategic Shifts, Required capability Uplifts and Initiatives

Table 2 FGO Strategy Strategic Shifts

Strategic shift	Description
Expanded Operating Lens and Control	Reflects incorporating decision-making data and insights from across the National Electricity Market (NEM) in how Powerlink operates the network. This shift improves utilisation of the transmission network by enhancing monitoring across Queensland and the NEM. It increases operational agility and enables flexible services capable of managing variability caused by growing weather dependent generation. The outcome is more integrated and responsive grid operations that maintains stability in a complex energy landscape delivering consumers greater reliability, resilience and cost-efficient operations.

Strategic shift	Description
Customer-Focused Operations	Refers to a broader strategic shift toward engaging with customers through their connections and contractual frameworks to access and optimise the inherent capabilities embedded within their assets — such as flexible load, controllable DER behaviour, and other operational characteristics. This approach enables Powerlink to work more closely with customers to support system operability by aligning commercial and technical arrangements with emerging power system needs, balancing customer value with system reliability and whole-of-system efficiency.
Innovative and Automated Operations	Involves forming strategic partnerships and embracing new technologies to automate operational processes and apply advanced analytics. This shift improves efficiency, reduces manual workload, and enhances decision-making through data-driven insights, allowing Powerlink to operate at scale enabling a more agile and resilient grid capable of adapting to rapid changes in the power system.
'Operate Big' Culture	Focuses on strengthening an operationally led strategic mindset across the organisation so that decision-making anticipates and manages the growing complexity of the grid. Embedding this approach positions the organisation to continually enhance operational efficiency and continue minimising costs for consumers.
Proactive but Selective Market Influence	Reflects Powerlink's strategic role in identifying whole-of-system efficiencies by engaging with generators and distributors upstream and downstream of the transmission network. From this system-wide vantage point, Powerlink can guide where emerging operational challenges are most effectively addressed, encouraging solutions to be delivered by the parties best positioned to act. This selective influence supports lowest-cost outcomes for customers by enabling efficient system optimisation without always requiring direct investment by Powerlink.

AEMO Engineering Roadmap and Operational Technology Roadmap

In December 2022 the Australian Energy Market Operator (AEMO) published their Engineering Roadmap to 100% Renewables.[1] This roadmap focused on what needs to be done, from an engineering perspective, to enable Australia's main interconnected power system to run reliably and securely at times without fossil fuels. One of the key messages from this roadmap detailed that:

'Operating the NEM power system is a real-time task, with control rooms and support functions at AEMO, NSPs and market participants working together to maintain a secure and reliable system 24 hours a day. It is critical to prepare for the first instance of any new operational condition in advance of that condition arising, and preparing for that first instance often also enables the system to operate under that condition on a regular basis.'

[1] AEMO Engineering Roadmap to 100% Renewables, 2022

With respect to power system modelling, the roadmap states that *'Current tools and capability will not be sufficient for AEMO and TNSPs to effectively model, with sufficient speed and accuracy, the range of phenomena and scenarios that will need be studied on the way to 100% renewable operation, or to support effective operation of real-time tools that rely on accurate power system models.'*

The EPRI Control Room of the Future[2] work has also identified 'Operational Monitoring and Decision Making' as an important research pillar that includes improved data visualisation and interpretation of data to improve decision making.

Similarly, AEMO's *Engineering Roadmap* makes clear that advancing operability is a shared responsibility across the power system. While AEMO leads market-wide coordination, TNSPs must also uplift their network-level operational capabilities, as many of the identified engineering challenges arise within, or are managed through, transmission networks. Progress toward the Roadmap's objectives therefore requires complementary capability development by both AEMO and TNSPs. Investment in operational tools is essential for Powerlink to continue supporting AEMO in meeting its obligations under the National Electricity Rules[3] (NER) and to stay aligned with AEMO's Engineering and Operational Technology Roadmaps. Strengthening Powerlink's capability to maintain robust real-time operations and operational planning functions is increasingly vital as the National Electricity Market becomes more complex. Without this investment, Powerlink risks falling behind in managing decentralised generation, rising weather dependent generation penetration, and emerging technologies, jeopardising compliance with NER requirements and AEMO's Schedule of Delegation for Powerlink[4].

Identified Need

The Future Grid Operations Technology (FGOT) investment addresses critical gaps highlighted in AEMO's Engineering Roadmap to 100% Renewables and Operational Technology Roadmap. These roadmaps underscore that existing operational tools and processes are inadequate for managing the complexity of a high-renewables grid while maintaining system security and compliance with the National Electricity Rules (NER). To meet these challenges, five high-level needs have been identified:

1. **Improved outage planning and execution** – Enhancing coordination and transparency to minimise disruption and optimise network utilisation.
2. **Reduction of operator cognitive load** – Integrating data analysis and decision-support tools to reduce human error and improve situational awareness in time-critical conditions.
3. **Reduction of curtailment during system normal and outages** – Leveraging forecasting and dynamic control capabilities to maximise generation integration and facilitate lower wholesale energy costs.
4. **Enable non-network solutions** – Provide an operational platform to facilitate use of non-network solutions resulting in lower cost to serve for consumers.
5. **Mitigation of unplanned reliability and loss of supply events** – Strengthening operational resilience to prevent costly outages and maintain consumer confidence.

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[2] Global PST Consortium - Vision for the Control Room of the Future Report compiled by EPRI, May 2023
[3] National Electricity Rules, Clause 4.3.4(a)
[4] AEMO Schedule of Delegated Functions, Powerlink Delegation Instrument

FGOT delivers targeted investments in forecasting, decision support, and Wide Area Monitoring, Protection and Control (WAMPAC) technologies. These capabilities directly respond to AEMO's call for uplift in control room systems, advanced analytics, and cyber-secure architectures, ensuring Powerlink can operate a secure, efficient, and consumer-focused transmission network in a rapidly evolving energy landscape.

Maturity Assessment

A capability assessment was completed which identified critical capability gaps that must be addressed through strategic investment to continue delivering safe, reliable, and affordable electricity through this transition. These needs fall into three key areas; each aligned with a portfolio of initiatives in the Future Grid Operations Technology (FGOT) program and directly linked to the benefits outlined later in this investment overview:

- **Forecasting & Data Support** – Better forecasting, analytics, outage planning and operational risk assessment capabilities to better anticipate and plan for changing conditions.
- **Decision Support & Situational Awareness** – Improving real-time visibility and operator tools to manage a more complex grid in real time.
- **Wide-Area Monitoring, Protection & Control (WAMPAC)** – Expanding dynamic control schemes and leveraging high-speed monitoring to maximise network utilisation, maintain system stability and defer network augmentation.

Each of these needs addresses specific operational challenges in the future grid environment, as detailed below, and together they ensure Powerlink can meet its obligations and deliver consumer benefits in the next regulatory period. Post-completion of the Next Generation Network Operations program, Powerlink is anticipated to have the following maturity post completion of the Next Generation Network Operations program (Table 3).

Table 3 Operational Capabilities and Maturity

Theme	Capability	Maturity[5]
Forecasting and Data Support	Operational forecasting	Initial
	Outage management	Established
	Operational data management	Emerging
	Operational risk assessment	Initial
Decision Support and Situational Awareness	Integration of information systems	Emerging
	Real-time contract management	Initial
	Alarm management	Initial
	Switching management	Initial
	Site access management	Emerging
	Dynamic ratings	Established
	Emergency Dispatch	Initial
WAMPAC	Control scheme management	Emerging
	Real-time monitoring	Emerging

[5] Anticipated maturity post completion of the Next Generation Network Operations program

Future Grid Operational Technology Investment Roadmap

Powerlink has developed a Future Grid Operations Technology Roadmap that sets out the capability uplifts and investments required for Powerlink to operate the Queensland transmission network safely, efficiently, and securely, in the context of a rapidly evolving energy system.

Powerlink has defined three areas of focus that that capture a portfolio of initiatives contributing to the delivery of more flexible, resilient, and efficient grid operations. Collectively, they aim to strengthen Powerlink's operational capability as a transmission network service provider in a rapidly evolving energy system.

Forecasting and Data Support

This theme focuses on uplifting Powerlink's ability to anticipate and respond to short, medium, and long-term changes in demand, generation, and system conditions. It includes initiatives to enhance forecasting capabilities across load, generation (including rooftop PV and batteries), weather (due to large amounts of weather dependent generation), and asset performance.

Decision Support and Situational Awareness

Improved decision support and situational awareness is imperative to Powerlink's ability to make timely, risk-informed decisions through enhanced data integration, visualisation, and analytics. This includes better use of Powerlink's existing datasets, particularly high-resolution time-series data combined with accessible market information (e.g., DER performance, weather, market data), and network-aware insights to create a more comprehensive operational picture.

By applying advanced data-visualisation tools, these initiatives aim to present information to real time operations in a way that enhances cognitive recognition of network conditions, supports faster detection of emerging risks, and enables the use of operational triggers to guide consistent, informed decision-making.

WAMPAC

Powerlink already operates a baseline suite of WAMPAC capabilities that deliver material benefits today, including network capacity optimisation, capital deferral and market efficiencies through post-contingent, fast-acting wide-area protection schemes. As the system transitions, however, protection and control schemes are becoming more interactive and complex, increasing the risk of cross-scheme interactions, an issue highlighted in AEMO's 2025 General Power System Risk Review (GPSRR).

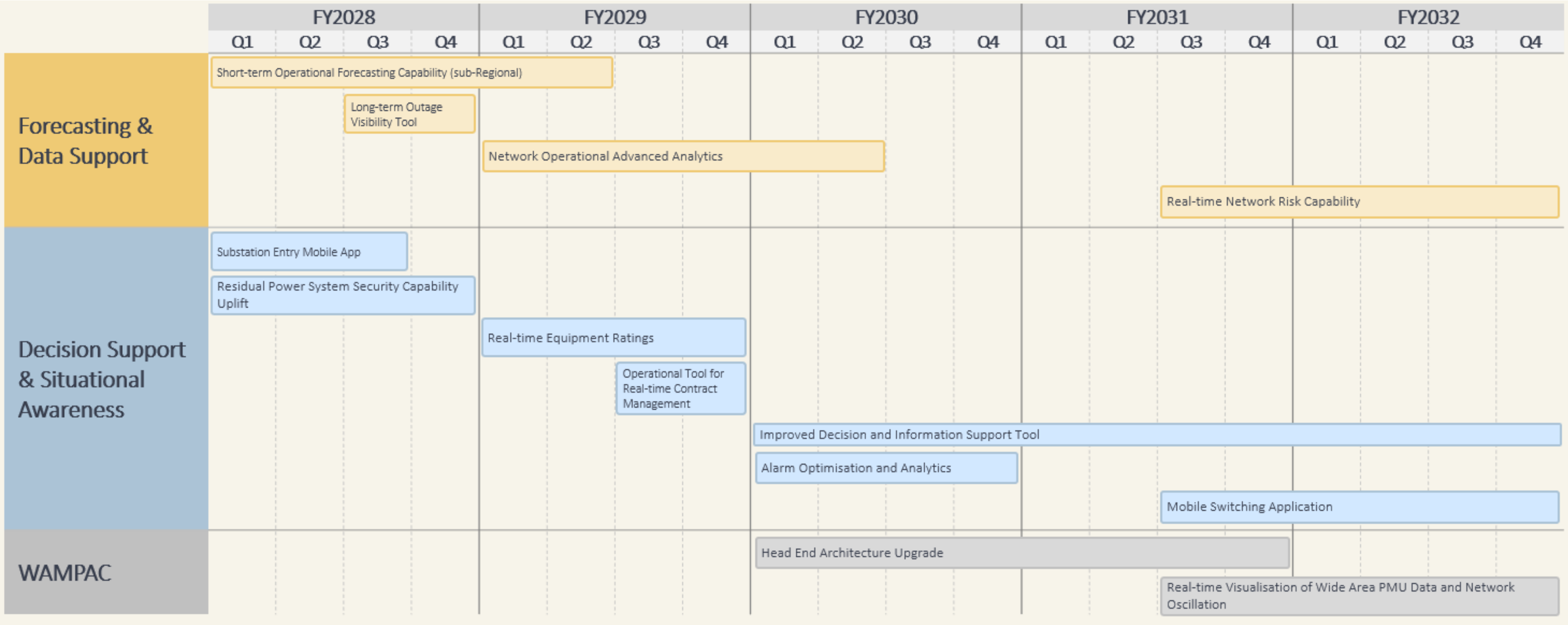
The FGOT WAMPAC investment builds on Powerlink's existing platform by enhancing WAMPAC's ability to assess global scheme behaviour, identify cross-interactions, and analyse stability and small-signal performance across the network. This includes upgrading the WAMPAC head-end architecture and deploying analytics and visualisation tools that make better use of Phasor Measurement Unit (PMU) and time-series data, including emerging capabilities from battery storage, flexible loads and new connection services. The investment reflects a deliberate trade off; preserving the strong network and market efficiencies WAMPAC already delivers, while investing in targeted tools, visualisation and upgrades that manage increasing operability risk.

Although PMUs have been installed to meet AEMO's requirements, integrating these measurements into Powerlink's operational systems is now essential to support the operation and ongoing optimisation of the Queensland transmission network. Leveraging this data provides the visibility needed to understand network performance and operating limits under rapidly changing and transient power system conditions, particularly as inverter-based technologies introduce more variable, software driven and interactively controlled behaviours. Enhanced insight into these dynamics enables Powerlink to detect emerging instability risks, identify cross interactions between protection and control schemes, and respond to the operational challenges outlined earlier. This uplift ensures WAMPAC continues to support secure and efficient system operation while complementing the significant network and market efficiencies already being delivered.

FGOT Roadmap by Investment Stream

The FGOT Roadmap by Investment Stream outlines a structured approach to enhancing Powerlink's operational capabilities in response to the evolving energy landscape. Each investment stream within this roadmap has been developed through a structured analytical approach. This ensures that the proposed initiatives are prudent, efficient, and deliverable, supporting Powerlink's commitment to delivering safe, reliable, and affordable electricity to Queenslanders. Figure 5 provides the FGOT 2027 – 2032 roadmap by investment stream.

Figure 5 FGOT 2027 - 2032 Investment Overview by Investment Stream



Preferred Option: Capability Uplift

The Capability Uplift scope of investment for each investment stream is provided below. These have been prepared to ensure Powerlink's operational technology is fit for future purpose.

Forecasting and Data Support

The Forecasting and Data Support Capability Uplift option leverages existing tools to create sub-regional and substation short term forecasts (30 min and 7 days ahead) using the Powerlink data verse, forecasts obtained from AEMO and Energy Queensland, and localised weather data. Establishing a platform for operational data analytics and providing long term visibility of outages will improve Powerlink's forecasting capability and inform planning and contingency analysis risk-based decisions.

The scope of this option includes the following initiatives:

- **Short-term Operational Forecasting Capability (Sub-regional):** Building a short-term forecasting analytics platform, leveraging existing Powerlink data and feeds from AEMO and Bureau of Meteorology, that can support sub-regional and substation operational forecasts.
- **Long-term Outage Visibility Tool:** Developing an enhanced Power BI-based visibility tool that provides a long-term forward view of planned outages by leveraging the existing OMS, connecting with the portfolio of works and incorporating network access constraints.
- **Network Operational Advanced Analytics:** Creating a centralised real-time data repository which links existing PI Historian data to the network model, OMS, Incident Management System (IMS), and other operational data sources, that can be used to integrate network performance to support operational decision making.
- **Real-time Network Risk Capability:** Implementing an offline power system simulation tool that will enable operational planning engineers to analyse network scenarios, perform a risk analysis of different network events, provide a risk rating and identify potential risk mitigations.

Decision Support and Situational Awareness

The Decision Support and Situational Awareness Capability Uplift option improves control room visibility and situational awareness for network controllers. It includes data analysis and tools that facilitate proactive decision support including digital dynamic ratings to optimise network and asset utilisation.

The scope of this option includes the following initiatives:

- **Improved Decision and Information Support Tool:** Modular single display for controllers that includes amalgamated data sources and decision support tools.
- **Operational Tool for Real-time Contract Management:** A centralised repository for network support and connection agreements linked to the existing Customer Relationship Management (CRM) system and easily accessed by network controllers to enable cost effective operation of non-network solutions.
- **Alarm Optimisation and Analytics:** Alarm optimisation and situation awareness enhancements including reporting and analytics that identify trends in alarms that can be used to identify opportunities for further alarm optimisation.
- **Mobile Switching Application:** Deploying a mobile switching application that includes digital switching sheets and permit management integrated with AEMS using a digital switching module for the control room and provision of digital switching sheets to the field.

- **Substation Entry Mobile Application:** Developing a mobile field companion app that enables field crew to log entry/exit into substations, providing real time visibility to the control room and reduce volume of control room phone calls.
- **Real-time Equipment Ratings:** Replacing the legacy dynamic line rating input system with a secure, integrated platform integrated into Powerlink's AEMS that uses real-time telemetry and asset data to optimise real time equipment and line ratings.
- **Residual Power System Security Capability uplift:** Developing a basic decision support tool to guide controllers should local dispatch be required following a High Impact Low Probability type event that renders AEMO unable to undertake its usual responsibilities e.g. a communication outage.

WAMPAC

The WAMPAC Capability Uplift option includes the continued development of the head end architecture and infrastructure to allow for expandability and flexibility of the WAMPAC platform. It supports high volumes of coordinated protection and control schemes using high-speed telemetry and implements third party interfaces to receive data for monitoring purposes and send controls for agreed services. This will enable coordinated integration of flexible loads and generation such as battery storage that can be leveraged to increase utilisation of the existing network, thereby reducing non-credible risks and facilitating deferral of future network augmentation. This is a capability with the flexibility to adapt as new, unforeseen network requirements need to be addressed.

The scope of this option includes the following initiatives:

- **Head End Architecture Upgrade:** Upgrade head end architecture to enable scalability and support high volumes of new technology such battery storage and DER. Improve telemetry and communication protocols enabling more sophisticated, scalable and faster control schemes to be implemented.
- **Real-time Visualisation of Wide Area PMU Data and Network Oscillation:** Leverage existing PMU data feed into AEMS internal applications such as state estimator and real-time small signal stability. Replace the existing offline PMU data analysis tool reaching end-of-life (with technical and licence limitations) with a modern equivalent enabling basic real-time monitoring and alerting of oscillations with a dashboard for both planners and operators.

This option establishes a platform that can accommodate multiple complex schemes into a centralised and coordinated approach (Figure 6).

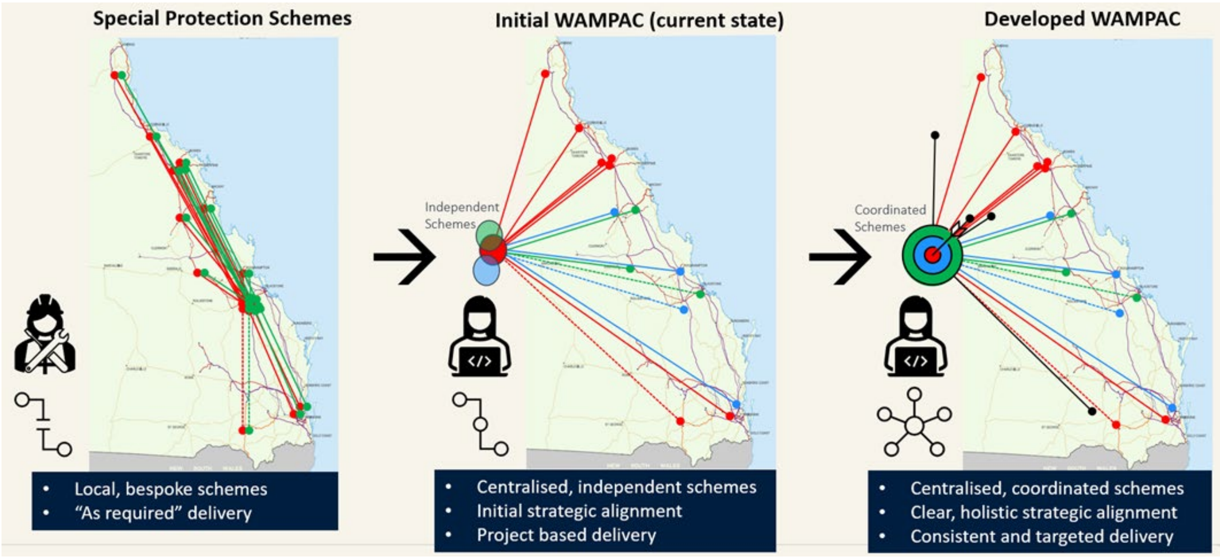


Figure 6 WAMPAC Evolution

Benefits

Qualitative Benefits

There are several key qualitative benefits from the FGOT investment streams as summarised in Table 4.

Table 4 Summary of Investment Stream Qualitative Benefits

Benefit	Benefit Description
Forecasting & Data Support	
Enhanced Risk and Outage Planning	• Improved scenario risk visibility (network outages, severe weather, load risk) • Forward view of planned outages for better planning & customer coordination • Improved outage coordination to align new connection testing windows with suitable conditions for timely hold point testing during commissioning • Scenario-based planning for severe weather and contingencies • Sub-regional forecasting for improved outage and contingency planning • More robust event response preparedness
Operational Efficiency and Cost Avoidance	• Optimised outage planning and reduced engineering analysis time • Avoided remobilisation costs from cancelled/rescheduled outages • Reduction in outage duration and improved operational efficiency • Reduced unplanned outages and avoided load shedding
Data-Driven Decision Enablement	• Improved forecasting accuracy for informed outage scheduling and operations • Establishing a scalable dataset for real-time decision-making • Facilitates asset risk models based on demand/forecasting • Data platform supporting compliance, reporting and monitoring including ongoing benefits realisation

Decision Support & Situation Awareness	
Safety and Reliability	• Improved switching safety and crew safety (real-time visibility) • Reduction in asset operational risk • Avoided unserved energy and reduced restoration times
Controller Workload and Efficiency	• Reduced cognitive load and workload for controllers • Improved efficiency, accuracy, and repeatability of decision-making • Reduced decision delays and streamlined issue response • Improved productivity and coordination time
Scalability and Integration	• Scalable platform for integration • Maximise line and equipment utilisation to reduce congestion • Improve rating accuracy leveraging greater data sources • Automate data input and alignment from ratings system into AEMS
WAMPAC	
Resilience and Risk Reduction	• Avoided pre-contingent market curtailment • Supports operational risk reduction • Improved event response and stability awareness • Evaluation of scheme interactions for coordinated control
Monitoring and Stability	• Proactive oscillation detection with real-time and forensic stability insights • Enables real-time validation of system strength service provision
Scalable and Adaptable	• Scalable system providing additional network development options alongside traditional augmentation approaches • Operations adaptable to unforeseen network requirements • Centralised integration of batteries, flexible loads, and generation

Quantitative Benefits

Quantifying benefits for operational technology projects is inherently challenging and differs from traditional network investments for replacement or augmentation, which are assessed under the Regulatory Investment Test for Transmission (RIT-T). The FGOT initiatives involve multiple influencing factors and often present overlapping benefits across investment streams, making precise quantification difficult and assumption driven (Figure 7). While system variability and complexity drive the need for FGOT, they also warrant a careful filtering of potential benefits, with quantification limited to those areas where a reasonable and conservative evidence base exists.

To address this, Powerlink has adopted a hybrid approach considering bottom-up analysis at the initiative level with top-down assessment at the FGOT investment level. This approach provides structure while intentionally applying conservative assumptions to ensure benefits are not overstated. In particular, care has been taken not to place undue weight on high-impact, low-probability events, even though these events are central to the operational improvements the FGOT program is designed to support.

The identified quantitative benefits of the FGOT investment case include:

- Reduction in curtailment during system normal and outages
- Reduction in unplanned reliability and loss of supply events
- Improved outage planning and execution

- Reduced operator cognitive load
- Enabling non-network solutions

While this approach provides a structured framework, we recognise that assumptions underpin the benefit estimates. Underlying assumptions were drawn from relevant internal case studies and trends, such as internal Powerlink network experience supplemented by external sources including the Australian Energy Regulator and Australian Energy Market Commission. These assumptions were then tailored specifically to the Powerlink FGOT investment streams. Key inputs for each identified benefit were developed using conservative assumptions and were subjected to sensitivity analysis to assess how changes in these variables affect the net investment benefits in NPV terms.

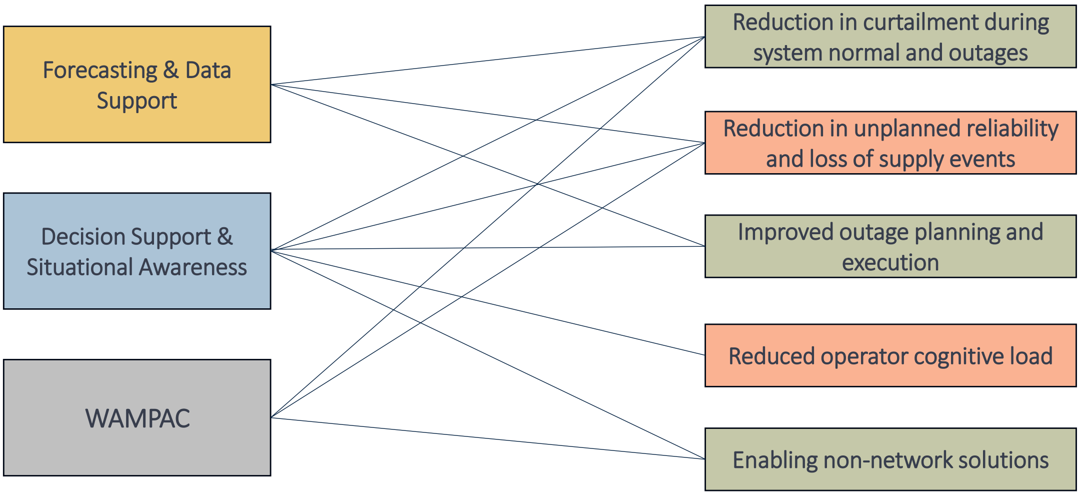


Figure 7 Investment Stream to Quantitative Benefits Mapping

Other options considered but not progressed

Transformational Uplift

This option builds on the Capability Uplift option. As part of assessing the future state of Powerlink's operational capabilities, a more transformational uplift pathway was examined to understand the potential longer-term trajectory of system operations. This pathway extends and significantly enhances the Capability Uplift approach, representing a more advanced and integrated operating model.

Key improvements are:

- enhanced control room visibility and situational awareness, providing controllers with richer and more integrated real-time operational information
- integration with the asset management system, including automated incorporation of maintenance information to support more coordinated and efficient outage scheduling
- application of AI and machine-learning tools in operational environments, including context-aware alarm management that reduces cognitive load and provides dynamically prioritised information

- expanded forecasting capability, extending to five-minute intervals at the power system element level with real-time data assimilation and model adjustment fully integrated into AEMS to support operational functions such as voltage control
- increased automation and more sophisticated sensitivity analysis, enabling a wider range of power-system scenario assessments to improve the quality and timeliness of operational decision-making

Many elements of this option are more suited for implementation in the next regulatory period (2032-2037) due to:

- The expanded capability and higher levels of automation and AI rely on emerging technologies that carry greater delivery, integration and technology-maturity risks. Early adoption of these elements would introduce significant complexity and may not represent efficient timing for investment.
- The benefits associated with the transformational pathway are expected to materialise later than those delivered through the Capability Uplift. The Capability Uplift allows core functionality to be deployed earlier, enabling Powerlink to validate performance, demonstrate benefit realisation and build an evidence base before contemplating any further enhancement. At this stage, the difference in expected benefits between the two pathways is not considered commensurate with the substantially higher level of investment required for a transformational uplift.

For these reasons, the transformational pathway has not been recommended as the additional cost and delayed benefits would present a lower NPV to the Uplift Capability option.

Increase in FTEs

Relying on an increase in Full-Time Equivalents (FTEs) as an alternative to the proposed FGOT investments is neither practical nor sustainable. For example, control room operators require approximately two years of on-the-job training, and there are inherent constraints on how many can be trained concurrently. As the network grows and operational complexity escalates, the marginal benefit of adding more personnel diminishes. There is an inflection point where additional FTEs cannot offset the systemic challenges posed by increasing complexity. Beyond this point, the strategy of simply scaling human resources becomes inefficient, ineffective and introduces significant operational risk.

Persisting with an FTE-based approach ultimately threatens system security and safety management of a high voltage network. Global experience shows that as networks become more intricate, reliance on manual intervention increases exposure to human error, which can lead to cascading failures. The trend of blackouts worldwide underscores the danger of administrative controls as the primary risk mitigation measure. Prudent proactive investment in engineering controls, such as those proposed by FGOT, offers a more robust and scalable solution. These controls are intended to reduce reliance on human decision-making under stress and provide systemic resilience, aligning with good industry practice.

Investment planning, governance, and delivery

Investment Planning Approach

Powerlink's investment planning is guided by a structured and risk-based assessment criterion, ensuring alignment with strategic objectives and regulatory requirements. This approach encompasses:

- **Strategic Alignment**: Ensuring that proposed investments support the Energy Roadmap, Powerlink's Corporate Strategy, Future Grid Operations Strategy, and Enterprise Priorities
- **Regulatory Compliance**: Aligning investment initiatives with obligations outlined by the AEMO and the Australian Energy Market Commission (AEMC), including system strength and inertia requirements in accordance with the National Electricity Rules.
- **Risk Assessment**: Applying a proportionate, risk-based approach to prioritise investments that address critical operational challenges and emerging risks.
- **Benefit Assessment**: Evaluating both quantitative and qualitative benefits from investments, including undertaking a cost-benefit analysis
- **Stakeholder Engagement**: Incorporating feedback from customers, industry stakeholders, and regulatory bodies to inform investment decisions.

This methodology ensures that investments are both prudent and efficient, supporting the safe, reliable, and affordable operation of the Queensland transmission network.

Governance Framework

Powerlink has a well-established corporate governance framework that includes financial delegations of authority for capital expenditure. The investments identified in this document have been identified as future investment needs and as outlined in Powerlink's Expenditure Forecasting Methodology (June 2025) specific project details for investments at this early stage have not been finalised and or received project approval.

Delivery Strategy

The framework for program planning and delivery of the FGOT investments is shown in Figure 8.

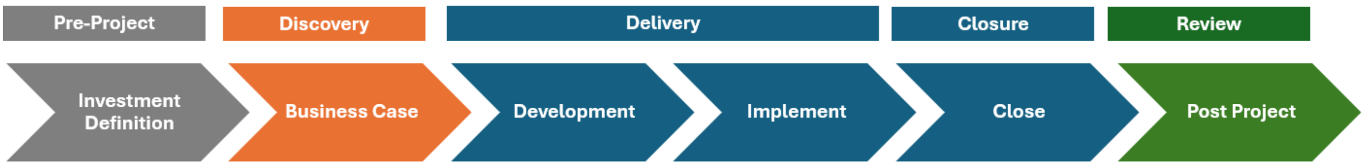


Figure 8 Timeline for delivery of Investment projects

The FGOT investments are all in "Pre-project" phase, which means the investment definitions and delivery dates have been proposed and are intended to be refined in later phases. The delivery approach for all projects is intended to leverage existing governance frameworks and delivery models used for Business IT and Network

Portfolio projects. The key delivery teams within the business have been engaged as part of the investment definition phase and have confirmed the resourcing approach and capacity to deliver in the proposed timeframes. A high-level change assessment has also been conducted considering the broader program of work and control room impacts. A full business case including market tested costs and benefits realisation and metrics will be developed under the "Discovery" phase. A resourcing and delivery plan including any testing, training and change management activities will be prepared during the delivery development phase.

Program design and dependencies

The program is structured with logical reasoning and flow between initiatives incrementally building on those beforehand, ensuring an integrated approach. Some initiatives are dependent on the successful implementation of work undertaken as part of the Next Generation Network Operations program such as the Advanced Energy Management System (AEMS) 'go-live' planned for August 2027. The FGOT program design is considerate of high-level resourcing requirements and key change impacts as well as potential advantages to undertaking some initiatives sequentially or in parallel with other business activities such an AEMS major upgrade. For example, there is an opportunity to strategically redeploy resources following AEMS go-live, transitioning from implementation activities to the design and execution phase of FGOT initiatives. This approach will leverage operational synergies, maintain continuity of expertise, and ensure alignment with Powerlink's systems, processes and future network needs.

Cost forecasting and estimation

The cost estimates used to prepare the initial investment streams and cost benefit analysis are based on a desktop analysis with input from Powerlink and external subject matter experts with experience of scoping and implementing similar operational technology (OT) solutions. The two options, Capability Uplift and Transformational Uplift were costed. These are compared with a base case (Counterfactual). Under the counterfactual, no additional investment is made to upgrade Powerlink's operational technology or control room tools. Costs have been estimated per project initiative, inclusive of program implementation, training and documentation. Benchmarking against industry peers shows that the proposed expenditure uplift is in line with sector-wide trends and supports the operational capabilities essential for the energy transition.

Costs will be allocated in line with the cost allocation methodology.

Cost-benefit analysis

Benefits for the preferred Capability Uplift option have been conservatively estimated at $12.3 million in NPV terms, demonstrating that the investment is expected to deliver a positive net benefit.

This outcome is reinforced by sensitivity analysis, which shows the option remains NPV-positive under varying input assumptions, and is further supported by the strong qualitative benefits associated with each investment stream. A cost-benefit analysis comparing the preferred option against the counterfactual of doing nothing was undertaken using pre-project estimates informed by a desktop study. Powerlink will apply its Benefit Management Framework throughout the project lifecycle to ensure benefits are consistently measured, tracked and realised.

Customer engagement

The FGOT investment streams were presented to Powerlink's Regulatory Proposal Reference Group (RPRG) in October 2025 and expectations regarding benefits modelling were discussed. The RPRG were generally understanding of the business need for the FGOT investment.

FGOT Capital expenditure forecast

Powerlink is proposing to spend $80.3 million (FY2026 Real) over the five-year regulatory period 2027-32. The forecast expenditure is provided in Table 5.

Table 5 Total FGOT capital expenditure ($m FY2026 Real)

	2027/28	2028/29	2029/30	2030/31	2031/32	Total
Forecasting and Data Support	6.6	8.5	3.8	1.9	2.8	23.6
Decision Support and Situational Awareness	2.8	7.1	10.4	11.8	12.3	44.4
WAMPAC	-	0.9	2.8	4.3	4.3	12.3
TOTAL FGOT Capital Investment	**$9.4**	**$16.5**	**$17.0**	**$17.9**	**$19.4**	**$80.3**

The FGOT preferred option provides a positive Net Present Value calculated to be $12.3 million which includes total benefits of $73.1m (NPV).

Governance and Approvals

Record of approval is via the approval functionality within objective, in line with the following.

Role	Contributor
Input	General Manager Real-Time Network Operations General Manager Energy & Digital Management Acting General Manager Business Information Technology Director Revenue Reset Manager Network Alternative Solutions
Recommend	General Manager Strategic Network Operations
Decide	Executive General Manager Operations & Planning (Strategy & Business Benefits) Executive General Manager Network Investment (Finance)

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12 December 2025

Mr Stewart Bell
Executive GM Operations & Planning
Powerlink Queensland
PO Box 1193
Virginia 4014
By Email: Stewart.Bell@powerlink.com.au

Dear Mr Bell

Support for Powerlink's Future Grid Operational Technology investment

Australian Energy Market Operator (AEMO) supports Powerlink's proposal to uplift the future grid operational technology, recognising the critical role this investment will make in supporting secure, reliable, and efficient network operations across Queensland and the National Electricity Market (NEM).

The need for this uplift is driven by the accelerating energy transition - including the integration of renewables, the retirement of legacy generation, evolving demand patterns, and the increasing complexity of system operations. To address these challenges and maintain system security, Powerlink is progressing a coordinated program of investment in new and enhanced operational technology and tools, which are fully aligned with AEMO's Operations Technology Roadmap and Engineering Roadmap. Several capabilities include:

- Short-term Operational Forecasting Capability (sub-regional)
- Network Operational Advanced Analytics
- Long-term Outage Visibility Tool
- Real-time Network Risk Capability
- Improved Decision and Information Support Tool
- Operational Tool for Real-time Contract Management
- Alarm Optimisation & Analytics
- Mobile Switching Application
- Substation Entry Mobile Application
- Real-time Equipment Ratings
- Residual Power System Security Capability uplift
- Head End Architecture Upgrade
- Real-time Visualisation of Wide Area PMU Data and Network Oscillation

These proposed upgrades are consistent with the experience of system and network operators in other jurisdictions, who are investing in the architecture, data, and tools required to operate, plan, and manage the power system of the future. Importantly, as AEMO has highlighted, there are interdependencies between AEMO and Transmission Network Service Providers (TNSPs), and our systems and capabilities must effectively interface, support, and complement each other.

Investments by AEMO alone will not be sufficient; a coordinated uplift by TNSPs such as Powerlink is essential to maintain system security and resilience across the NEM. These investments are urgently needed to manage the security of the power system and to complement AEMO's own roadmap and associated programs.

Powerlink and AEMO have engaged collaboratively to define emerging power system needs and the future operational technology and tools required to address them. We look forward to continuing to work together to refine and implement capability uplift solutions that will maintain a reliable and secure power system, in the best interests of consumers.

If you would like to discuss this matter further, please do not hesitate to contact me at Michael.Gatt@aemo.com.au.

Yours sincerely,

[redacted]

Michael Gatt

Chief Operations Officer