AEMO Operations Technology Roadmap

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

CSIRO

Executive Summary Document
June 2022

Important Notice

Purpose

AEMO publishes this document for information purposes in connection with its Australian electricity system and market operation functions. The operational capability needs identified in this document are based on projections of power system development consistent with AEMO's most recent forecasting and planning reports prior to the time of publication.

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Introduction

Setting the Context for the Operations Technology Roadmap

The Australian electricity sector is unique in its current status leading the world in terms of renewable and distributed renewable integration while also projecting radical and transformative levels of growth in renewable energy in the decade ahead.

The roadmap identifies the system and market operations capability needs to enable this transformative change while maintaining electricity system reliability, security and resilience.

Acknowledgements

AEMO and CSIRO acknowledge the input and contribution from a wide range of internal and external industry stakeholders in developing the 2022 Operations Technology Roadmap, in particular:

- EPRI including supporting partners Strategen, GridOptimize and Hoffman Power Consulting.
- System Operators from the Global Power System Transformation Consortium: ERCOT, Energinet, California ISO, Eirgrid and National Grid ESO.

All acronyms are defined at the end of this report.

OTR Project Scope, Team, Structure and Engagement

In late 2021 AEMO and CSIRO (Commonwealth Scientific and Industrial Research Organisation) engaged EPRI (Electric Power Research Institute) and a team of consultants from Strategen, GridOptimize and Hoffman Power Consulting to work with a dedicated AEMO National Electricity Market (NEM) and Wholesale Electricity Market (WEM) project team to develop an Operations Technology Roadmap for AEMO. The roadmap is intended to build on work carried out by EPRI and Strategen for CSIRO in 2021 as part of the Global Power System Transformation (G-PST) initiative. The project team sought and received input from the founding system operators of the G-PST to ensure the proposals were aligned with international best practices.

The project was split into five workstreams, structured around the EPRI control room of the future framework. An engagement plan was developed around a broad workshop in December 2021 with the full range of AEMO stakeholders, followed by targeted follow up engagements with individual subject matter experts (SMEs).

The OTR is required to uplift operational capability to allow AEMO manage the complex system of the future. It is tied in directly to ongoing AEMO initiatives, in particular, the Engineering Framework (EF), by linking the EF gaps to OTR gaps (WS1), as well as the AEMO future state architecture project, by collaborating on a business capability model (WS2). The project team also collaborated extensively with the AEMO NEM2025 and WA Market Reform teams and experts.

The OTR is an expansive and ambitious vision and guideline for the future of operations technology in AEMO. Due to the uncertainty in future trajectory, it may evolve or diverge in the years ahead to meet the future system requirements and decisions made about the operating model in the Australian electricity sector. The OTR should be routinely reviewed and be refined as the needs change.

WS1 – Current Status, Vision for OTR

WS2 – Business Capability Model and Architecture

WS3 – Data and OT Software Applications

WS4 – Facilities Hardware and Human Factors

WS5 – Technical and Executive Summary Report and Presentation

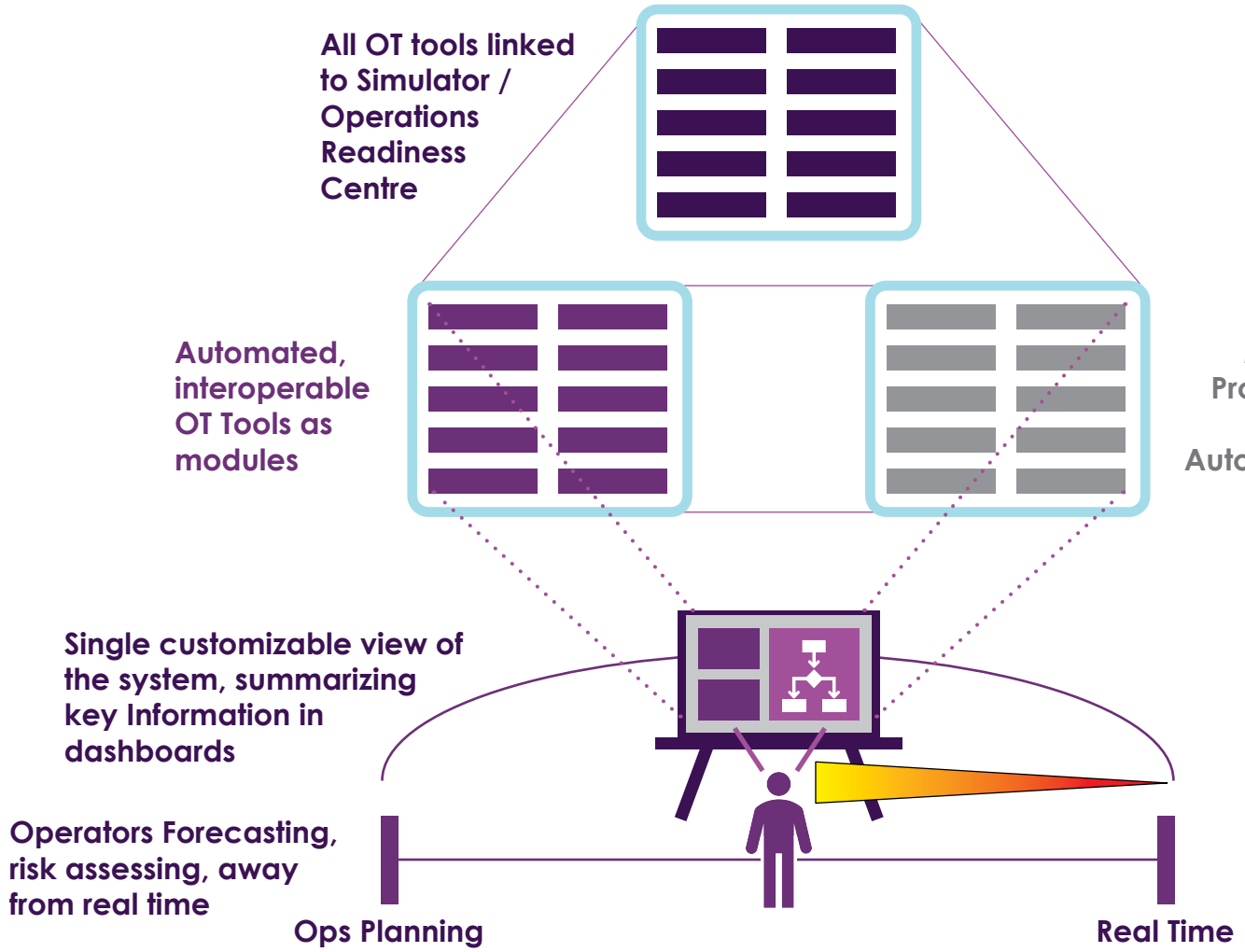
Vision Statement

"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."

EPRI Control Room of the Future Framework

EPRI has an established methodology and framework when developing roadmaps and research associated with transmission system control rooms of the future (CROF). This is a complex, interconnected model, with four foundations and eleven pillars all supporting the purpose and vision for the CROF. This was developed in consultation with key stakeholders during the development process.

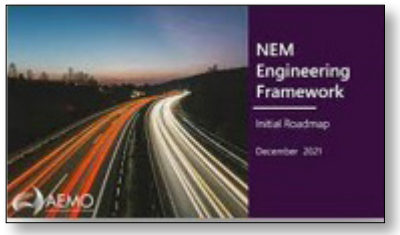
The framework establishes a pathway to develop a future system operations vision, shown right. In this vision of future operations, operators engage with OT tools via a streamlined interface. They act further from real time, risk assessing the system trajectory based on forecasts. The OT tools are interoperable and while automated processes dominate, manual backup is available at all times. All OT tools are mirrored in a training simulator or operations readiness centre environment.



OTR Gaps Mapped to Control Room of the Future Foundations and Pillars

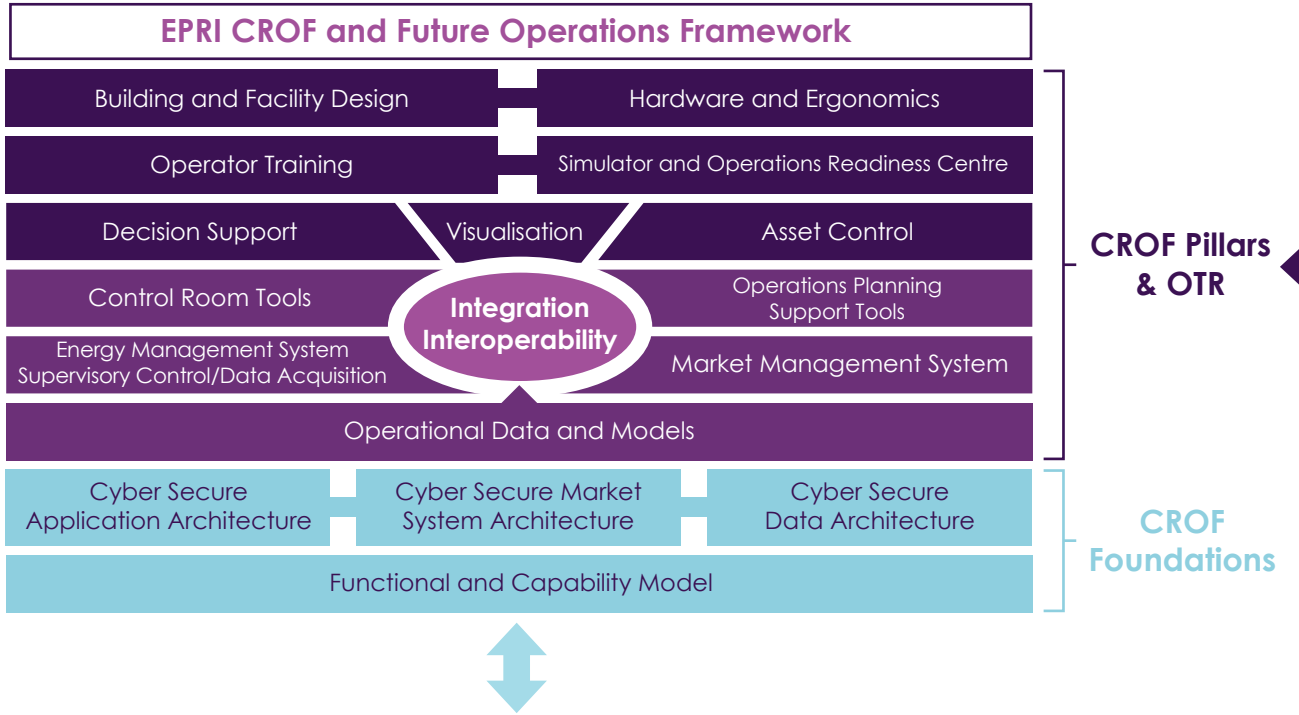
Having a well-structured framework and vision for future control room operations and the operations planning function is helpful for mapping the gaps identified. The OTR can be developed in a structured manner, where the OTR gaps can be linked to foundations or pillars of the framework. A framework for the study of the future control room needs in the Australian context was developed by EPRI for CSIRO in 2021 and aligns with the G-PST initiative. The framework is shown below.

The OTR project was structured on the CROF framework with the foundations (capability model and architecture) the data and OT tools and the building, hardware and human factors. Key inputs include the engineering framework, ongoing market reform initiatives in NEM and WEM and the AEMO future state architecture project.



322 NEW Gaps → 50 OTR Gaps

NEW & WA Market Reform →



GLOBAL PST CONSORTIUM

CSIRO

Source: Developed by EPRI for CSIRO as part of the Australian Research Plan for the Global Power Systems Transformation (G-PST) program in 2021

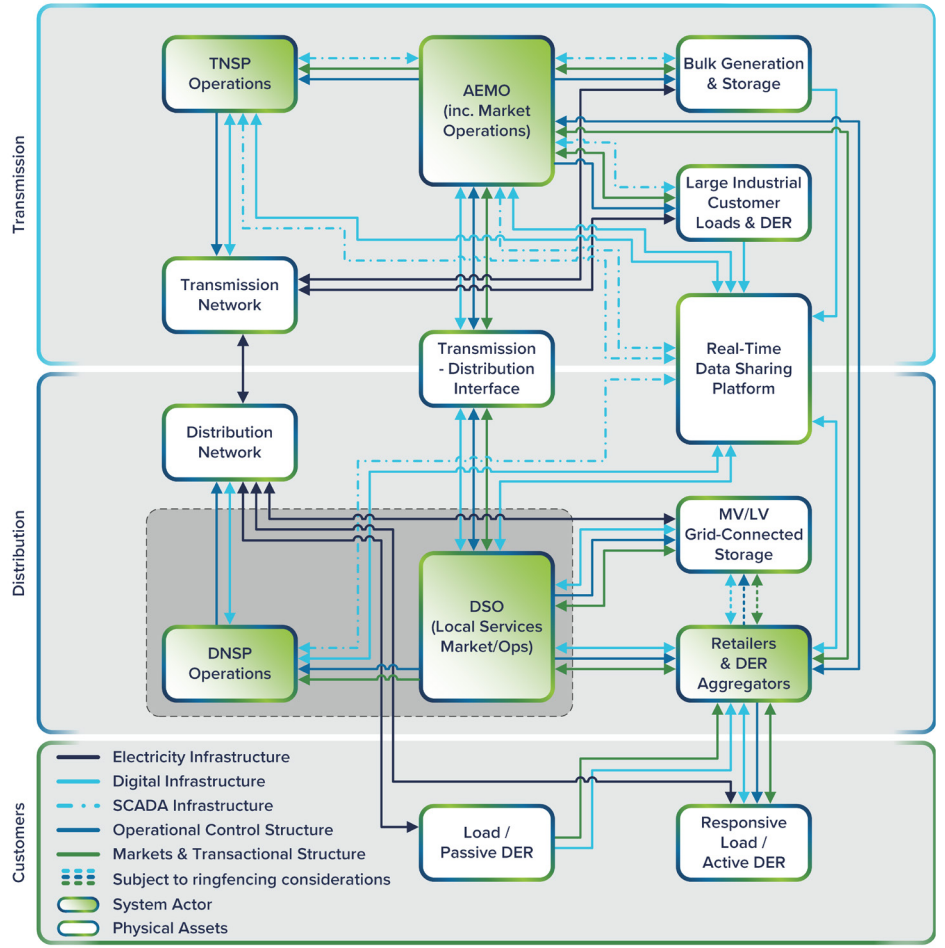
Illustrative *Step Change* Architecture

A power system with very high levels of variable renewable energy is more dynamic and complex. AEMO's *Step Change* scenario describes such a future and would require shifts in the system architecture. The 'Network of Structures' architecture diagram (right) illustrates how the many interdependent links between the various subsystems and actors may evolve for the needs of 2030+.

Important to Note - This diagram is illustrative only.

- It is not intended to be prescriptive or provide a single vision of the 2030+ future.
- It primarily illustrates the deep interdependencies of the many subsystems and actors in a modern power system and the importance of considering the entire 'Network of Structures' in any future system design.
- This particular illustration is informed by the 'hybrid model' currently being demonstrated and tested in Project Symphony and Project Edge.
- It also highlights the anticipated need for a real-time data sharing platform, for SCADA and market data, that can be accessed by AEMO and NSPs under any future architecture option (but does not detail all data categories shared).
- The actual enduring DER orchestration and Australian electricity sector operating models will be decided by regulators and stakeholders in the years ahead.
- The link between DNSP operations and a potential future DSO, which may be the same entity, is also highlighted (although its enduring architecture is yet to be determined).
- Illustrative architectures developed by Strategen build on the CSIRO G-PST Australian Research Roadmap - Phase 1 (2021) and further detail is expected to be developed in subsequent phases.

All Functional Layers – *Step Change* Future State



System Design Complexity

2022

- Current State Architecture

2025

- NEM and WEM Reform State
- Future State Architecture Project
- Hybrid Model for DER Orchestration

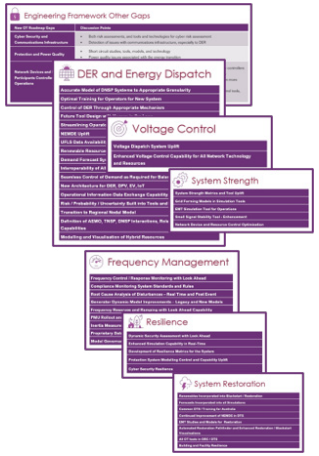
2030

- *Step Change* Scenario
- Illustrative Network of Structures Architecture

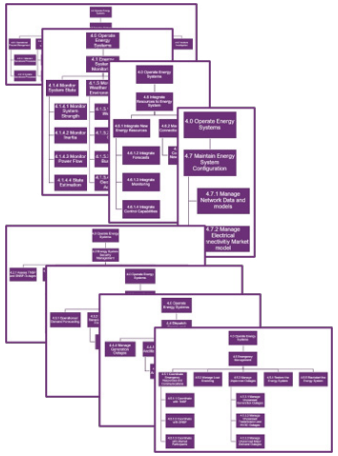
Linking System Architecture Initiatives

Identifying the OT gaps at an early stage allowed a detailed business capability model for AEMO network operations to be developed in partnership with the AEMO future state architecture project team. This foundational work will be the basis for establishing the OT tool requirements needed to meet the capabilities for the system of the future. A set of reference architectures for the OT tools can be utilised as OT tools are specified. Additionally, a 2030+ illustrative architecture, using the network of structures concept, shows how the systems may evolve beyond 2025 towards 2030+ to deliver the projected *Step Change* scenario.

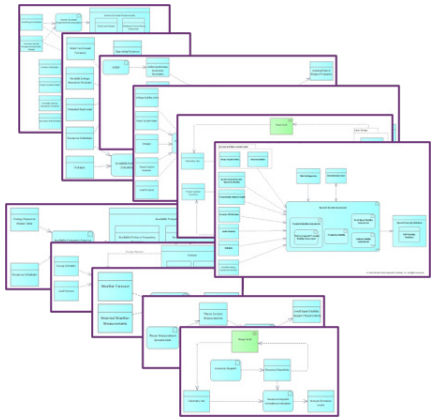
OTR Gaps



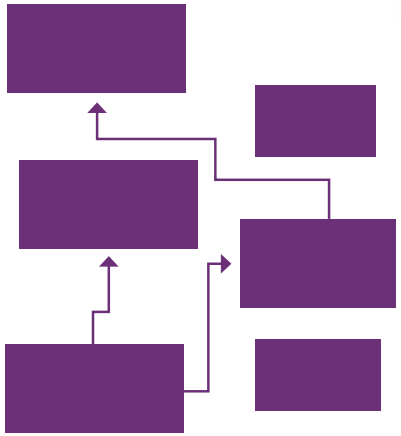
BCM



Reference Architectures



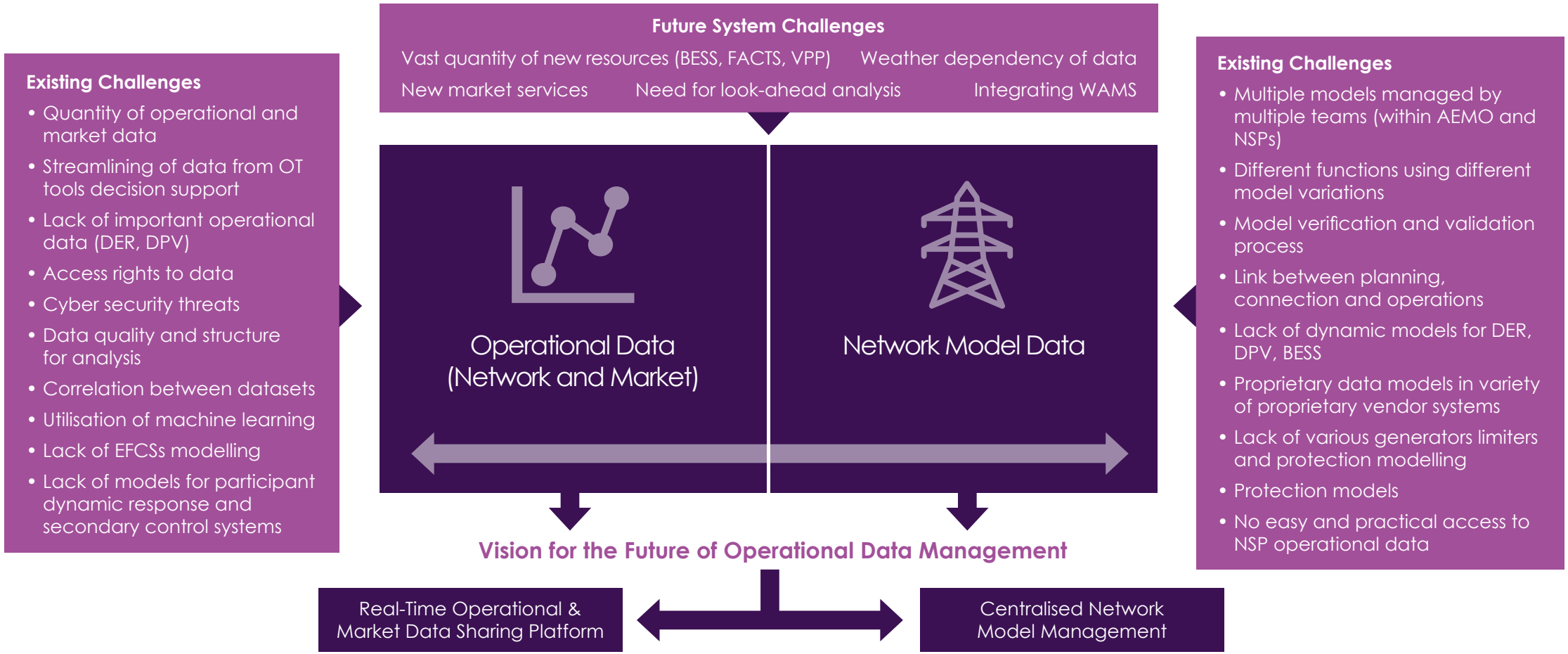
2030+ Architecture



Linked to the AEMO Future State Architecture Project

Current Data Process and Flow

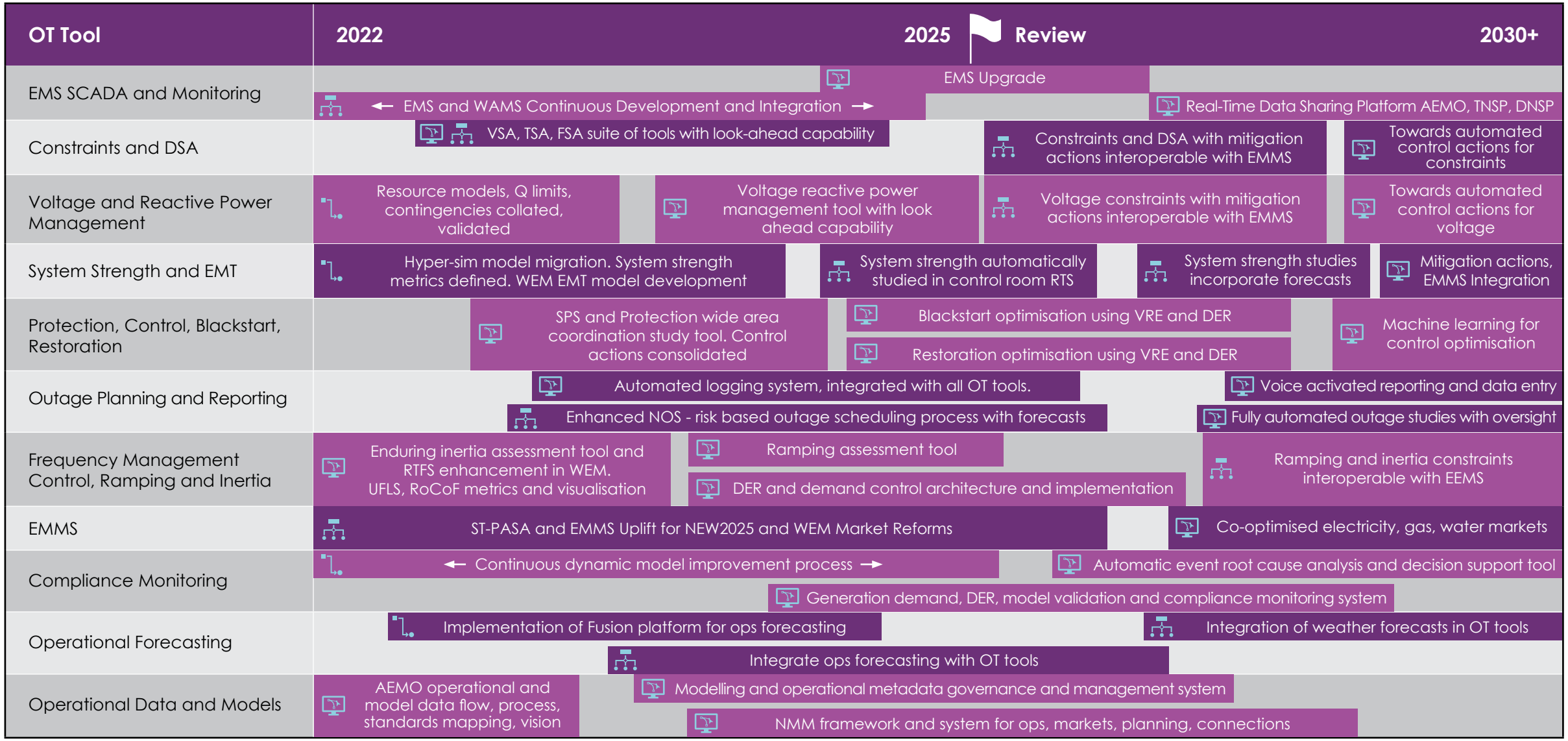
Given the exponential growth in resources and observable data points, the operational data domain faces multiple challenges today and for the future. To address this, it is proposed that the first step on the roadmap for data is to develop a vision for the future of data management for AEMO operations. This vision should completely map the operational and model dataflows and the modelling needs across AEMO while adressing legacy model issues. It should assesses the future needs, with exploration of a real-time operational market data sharing platform and a centralised model management process, platform or system.



Operations Technology Tools

OT Tools Proposed Projects and Initiatives, Including Important Existing Projects

Key: New Tool/Process Enhanced | Enhanced Existing Tool | Existing Process/Project



Note: A number of tools will be introduced into WEM operations as part of WEM reform in the coming years.

OT Tools Project Cost Ranges

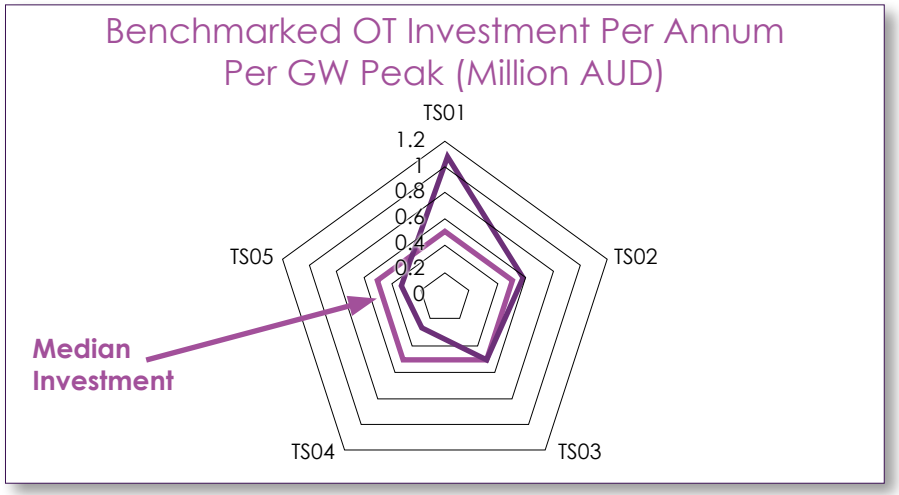
Developing Cost estimates or ranges for delivery of the complex program of tools, process improvements and systems is inherently challenging, especially when developing a long duration roadmap. The reasons why include:

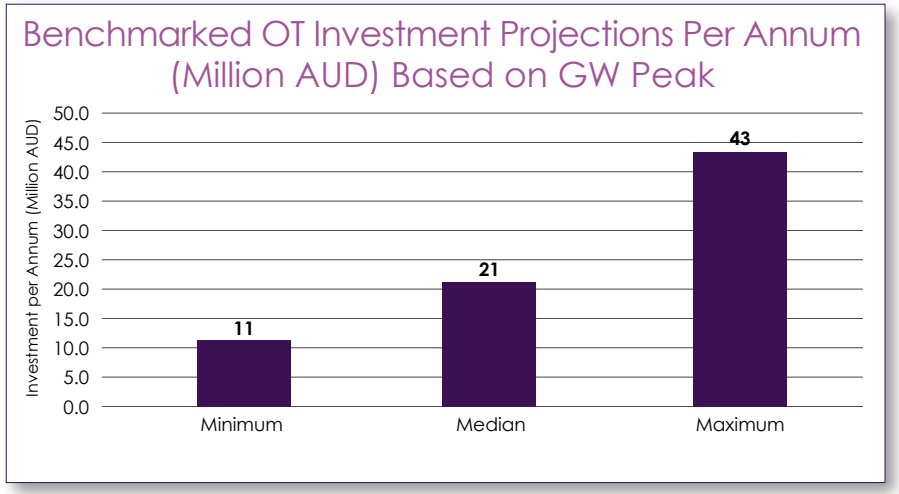
- Lack of access to vendor cost data for commercial reasons.
- Lack of information sharing between similar operator entities on costs of tools, even if they are of equivalent size.
- Combination of large monolithic vendor systems and smaller niche software system and platforms.
- Some tools developed in-house with smaller capital outlay and larger human resource investment for development.
- Scope of tools is visionary in nature and in some cases may not be possible without the box solutions, so its difficult to precisely cost at the outset.

All system and market operators, regardless of their location or functions, are undergoing similar radical shifts in their model of operation and are performing similar exercises to project ahead where architecture, data and tools will be required to operate the system of the future.

The OTR team developed estimates by comparing publicly available projected investment in control room and operational tools by five major system operators in the years ahead and baselining off their peak demand served or the transmission network footprint under control.

Investment includes business as usual costs, and human and capital resources, such as EMS, MMS upgrades, and should be read as a guideline.





Among five major TSOs, the median investment in OT tools is 0.53 Million AUD per GW peak per annum. Applying to AEMO NEM and WEM gives a range of 11-43 Million AUD per Annum, with a median estimate at 21.2 Million AUD Among five major TSOs, the median investment in OT tools is 0.32 Million AUD per 1000 km of network per annum.

Summary

The Australian power system is likely to undergo radical transformation to at least 2030 due to decarbonisation and decentralisation. The AEMO operations core capabilities will need to be equipped with the tools to manage the system in these scenarios.

The OTR was developed to address gaps identified by internal AEMO stakeholders (workshops and briefings) and external stakeholder input (AEMO's Engineering Framework). This gap analysis process can be replicated in the years ahead, as the OTR gets reviewed.

The OTR was developed with the best available information from early 2022. In the years ahead the OTR is flexible enough to evolve and adjust to regulatory changes, new roles and responsibilities. The OTR should be regularly reviewed for this purpose.

A business capability model was developed for AEMO to baseline the capabilities in operations. This work feeds into the future state architecture development and is a foundational process to identify and address needs in the years ahead.

An illustrative architecture was developed, based on the 'network of structures' concept, to illustrate how key subsystems are likely to become increasingly interlinked in the power system from 2030 onward.

An operational data and model roadmap was developed. This illustrates key needs for the future of data management in AEMO, in particular associated with operational data and network models management.

The sharing and standardisation of model and operational data will require extensive engagement between AEMO and the NSPs, to ensure the processes are streamlined and duplication of engineering effort is minimised. This will enable operators in all NSPs to have the best quality data available at all times to ensure optimal decision making.

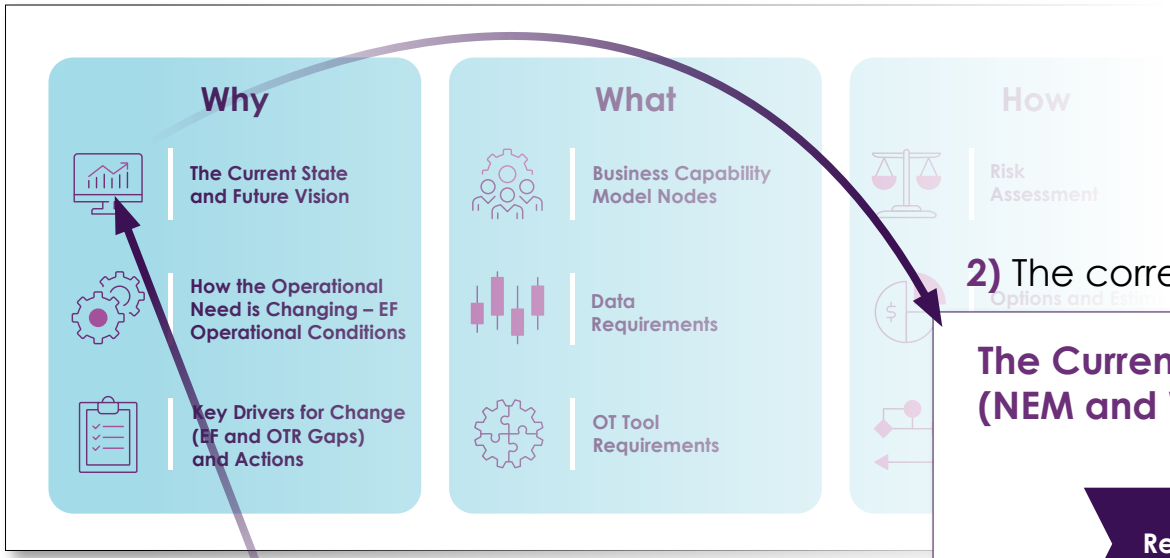
Detailed roadmaps for 10 OT tools were developed. Each roadmap extends to 2030 and includes a future vision, drivers for change, risk assessment, high-level cost benefit, data requirements and OT tool requirements. An indicative timeline for development to 2030 is also included, with review in 2025-26.

Roadmaps for aspects related to operator human factors, buildings and facility design and hardware and equipment are also developed as key components of the OTR. It is noted that AEMO currently has very advanced capability in these areas.

Important aspects of OT tool development such as cyber security, software development processes and the use of artificial intelligence are discussed with reference to the roadmaps. An indicative investment estimate is provided, based on benchmarking with equivalent system operators internationally, outlining the scale of investment required to implement the roadmaps.

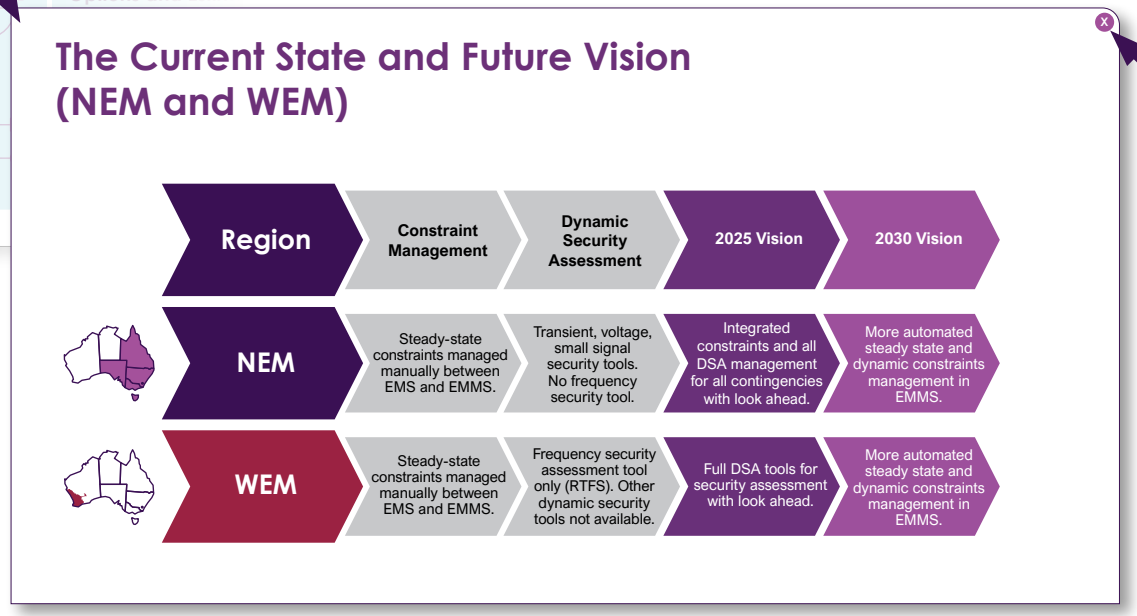
How to Interact with the Roadmap

OT Tools Roadmaps are in interactive PDF format.



1) Click on any of the 9 icons

2) The corresponding graphic will popup



3) Click the X to exit

Operational Data and Models

Why

The Current State and Future Vision

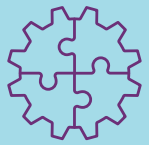
How the Operational Need is Changing – EF Operational Conditions

Key Drivers for Change (EF and OTR Gaps) and Actions

What

Business Capability Model Nodes

Data Requirements

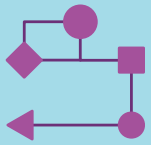


OT Tool Requirements

How

Risk Assessment

Options and Estimated Cost Benefit



A Roadmap for Development through 2030+

Operational Forecasting

Why

The Current State and Future Vision

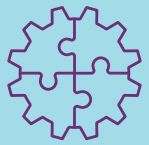
How the Operational Need is Changing – EF Operational Conditions

Key Drivers for Change (EF and OTR Gaps) and Actions

What

Business Capability Model Nodes

Data Requirements



OT Tool Requirements

How

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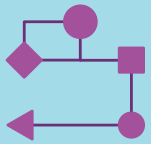
Options and Estimated Cost Benefit



A Roadmap for Development through 2030+

Compliance Monitoring

Why

- The Current State and Future Vision
- How the Operational Need is Changing – EF Operational Conditions
- Key Drivers for Change (EF and OTR Gaps) and Actions

What

- Business Capability Model Nodes
- Data Requirements
- OT Tool Requirements

How

- Risk Assessment
- Options and Estimated Cost Benefit
- A Roadmap for Development through 2030+

EMS SCADA and System Monitoring

Why

The Current State and Future Vision

How the Operational Need is Changing – EF Operational Conditions

Key Drivers for Change (EF and OTR Gaps) and Actions

What

Business Capability Model Nodes

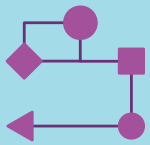
Data Requirements

OT Tool Requirements

How

Risk Assessment

Options and Estimated Cost Benefit



A Roadmap for Development through 2030+

Dynamic Security Assessment and Constraints – Incorporating Transient, Voltage and Small Signal Stability

Why

- The Current State and Future Vision
- How the Operational Need is Changing – EF Operational Conditions
- Key Drivers for Change (EF and OTR Gaps) and Actions

What

- Business Capability Model Nodes
- Data Requirements
- OT Tool Requirements

How

- Risk Assessment
- Options and Estimated Cost Benefit
- A Roadmap for Development through 2030+

System Strength and Electro-magnetic Transient

Why

The Current State and Future Vision

How the Operational Need is Changing – EF Operational Conditions

Key Drivers for Change (EF and OTR Gaps) and Actions

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Business Capability Model Nodes

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OT Tool Requirements

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Risk Assessment

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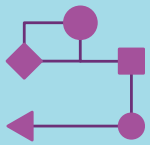


A Roadmap for Development through 2030+

Voltage and Reactive Power Management

Why

- The Current State and Future Vision
- How the Operational Need is Changing – EF Operational Conditions
- Key Drivers for Change (EF and OTR Gaps) and Actions

What

- Business Capability Model Nodes
- Data Requirements
- OT Tool Requirements

How

- Risk Assessment
- Options and Estimated Cost Benefit
- A Roadmap for Development through 2030+

Protection, Control, Blackstart and Restoration

Why

The Current State and Future Vision

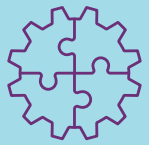
How the Operational Need is Changing – EF Operational Conditions

Key Drivers for Change (EF and OTR Gaps) and Actions

What

Business Capability Model Nodes

Data Requirements

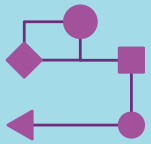


OT Tool Requirements

How

Risk Assessment

Options and Estimated Cost Benefit



A Roadmap for Development through 2030+

Electricity Market Management System

Why

The Current State and Future Vision

How the Operational Need is Changing – EF Operational Conditions

Key Drivers for Change (EF and OTR Gaps) and Actions

What

Business Capability Model Nodes

Data Requirements

OT Tool Requirements

How

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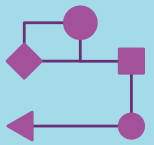

A Roadmap for Development through 2030+

Frequency Management and Control, Ramping and Inertia

Why

The Current State and Future Vision

How the Operational Need is Changing – EF Operational Conditions

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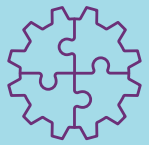
Data Requirements

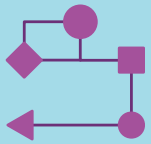


OT Tool Requirements

How

Risk Assessment

Options and Estimated Cost Benefit



A Roadmap for Development through 2030+

Outage Management and Reporting

Why

- The Current State and Future Vision
- How the Operational Need is Changing – EF Operational Conditions
- Key Drivers for Change (EF and OTR Gaps) and Actions

What

- Business Capability Model Nodes
- Data Requirements
- OT Tool Requirements

How

- Risk Assessment
- Options and Estimated Cost Benefit
- A Roadmap for Development through 2030+

Key Dependencies and Challenges

OT Tool	External Dependencies	Internal Project Dependencies	Challenges
EMS SCADA and Monitoring	Future DER Operating Model Decision Links to NSP operational data	P1920 High Speed Monitoring, Future State Architecture P1523 RTNET upgrade	Available vendor solutions to requirements
Constraints and DSA	Up-to-date network asset limits, generator dynamic models	P1845 SSAT Uplift	Dynamic model availability and accuracy, compute power and complexity Integration challenges
Voltage and Reactive Power Management	Links to NSP and generator operational data and models	VDS Uplift	New asset and resource capability models and data availability Integration with VSA
System Strength and EMT	TNSP data and model availability in real time, industry connections tool	EMT model and real-time simulator development	Dynamic model availability and accuracy, compute power for fast solutions Software development resources
Protection, Control, Blackstart and Restoration	TNSP data and model availability in real time	Future State Architecture Project	Available vendor solutions to requirements or software development resources Capability of DER, VRE
Outage Planning and Reporting	TNSP and generator data and model availability	P1548 NOS Improvements	Uncertainty in outage planning and system variability Resource intensive
Frequency Management Control, Ramping and Inertia	NEM2025 Reforms, Future DER Operating Model Decision	P1942 Frequency Performance Management System	Roles and responsibility definition Span of control from AEMO
EMMS	NEM2025 Reforms, Future DER Operating Model Decision	P1608 ST-PASA Uplift	Maintaining system reliability while upgrading Regular rule changes
Compliance Monitoring	Dynamic model availability	P1920 High-Speed Monitoring	Lack of high-speed recorders and PMUs
Operational Forecasting		P2046 Ops Forecasting, Fusion platform	Vendor forecast and DER data availability
Operational Data and Models	DER Operating Model Decision	Future State Architecture, Digital Strategy, CoDMaStR	Resourcing for centralised data management initiative

Acronyms

AEMO	Australian Energy Market Operator
AUD	Australian dollar
BCM	Business Capability Model
BESS	battery energy storage system
CROF	Control Room of the Future
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DER	distributed energy resource
DNSP	distribution network service provider
DPV	distributed photovoltaic
DSA	dynamic stability assessment
DSO	distribution system operator
EF	Engineering Framework
EFCS	emergency frequency control schemes
EMMS	Electricity Market Management System
EMS	energy management system
EMT	electro-magnetic transient
EPRI	Electric Research Power Institute
ESB	Energy Security Board
EV	electric vehicle
FACTS	flexible alternating current transmission systems
FSA	frequency stability assessment
G-PST	Global Power System Transformation
GW	gigawatt
IBR	inverter-based resource
LV	low voltage
MV	medium voltage
MVAR	megavolt amp reactive
MW	megawatt
NEM	National Electricity Market
NEMDE	National Electricity Market Dispatch Engine
NMM	network model management
NSP	network service provider
OT	operations technology
OTR	Operations Technology Roadmap
PASA	Projected Assessment of System Adequacy
PMU	phasor measurement unit
PSCAD	Power Systems Computer Aided Design
RoCoF	rate of change of frequency
RTFS	real-time frequency stability
SCADA	supervisory control and data acquisition
SPS	special protection scheme
SSAT	small-signal stability assessment
SWIS	Southwest Interconnected System
TNSP	transmission network service provider
TSA	transient security assessment
UFLS	under frequency load shedding
VDS	voltage dispatch system
VPP	virtual power plant
VRE	variable renewable energy
VSA	voltage security assessment
WAMS	wide area monitoring system
WEM	Wholesale Electricity Market
WS	workstream

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For more information visit

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