Open Energy Networks Project:

Workshop to test Required Capabilities, test interactive meta-models and discuss CBA methodology

Energy Networks Australia & the **Australian Energy Market Operator (AEMO)**

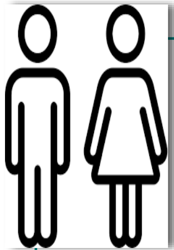
March 2019

Logistics & Safety

Emergency procedure…

Morning / Afternoon Tea –outside the conference room

Lunch – on site



Toilets – outside the conference room to your left/right

Workshop materials can be emailed

Workshop Ground Rules

Workshop Ground Rules

Full Agenda	Stick to schedule yet flex as necessary
Outcome Focused	Focus on clear outcomes and seek clear insights from the group
Open Engagement	Inquire by asking questions Building by using AND instead of BUT Challenging by using 'What if' Creating by using 'How might we'
Response	Everyone has the opportunity to provide feedback

Important Notice

- These slides are solely for workshop purposes only. The contents have been designed to foster a diversity of thinking about future possibilities in Australia. They do not represent the official position of either the Energy Networks Australia or AEMO.
- ‘Chatham house’ rules apply
- Competition and Consumer Act provisions apply

‘Open Energy Networks’ Project - Workshop Agenda

10:00 – 10:15 ***Welcome & Introduction to the Workshop***

10:15 – 11:30 ***Session 1: Required Capabilities and Actions***

- 1st Order Required Capabilities
- 2nd Order Common areas of Action

11:30 – 12:30 ***Session 2: 4th Model***

- Provide background and rationale regarding the addition of the 4th model

12:30 – 1:15 **Lunch**

1:45 – 3:15 ***Session 3: Market model framework modelling***

- Outline key outcomes/talking points from modelling
- Demonstrate the interactive html files on SGAM modelling

3.15 - 3.30 **Afternoon Tea**

3:30 – 4:55 ***Session 4: Cost Benefit Analysis***

- Outline approach for deeper justification of optimisation and DSO
- Outline approach to qualitative assessment of market model frameworks

4:55 – 5:00 ***Workshop Wrap up & Close***

- Summarise day and next steps

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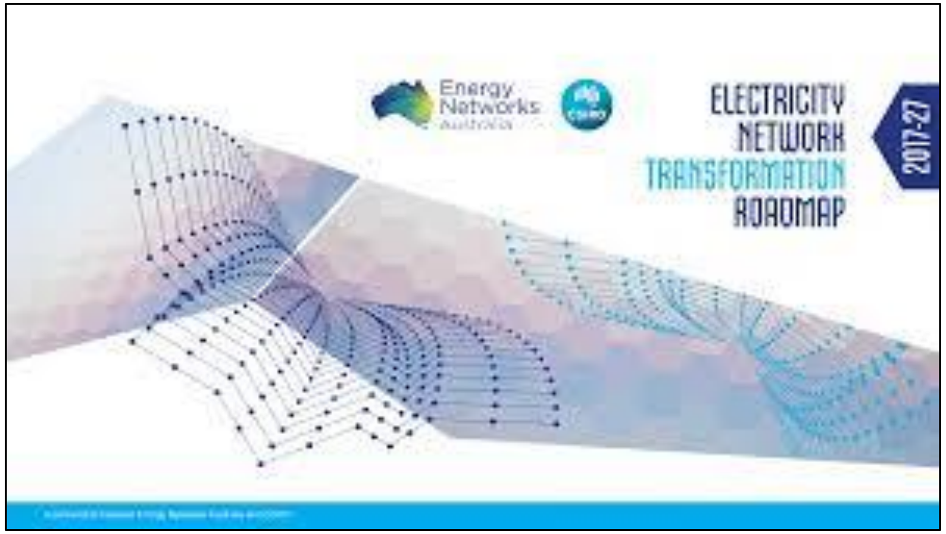
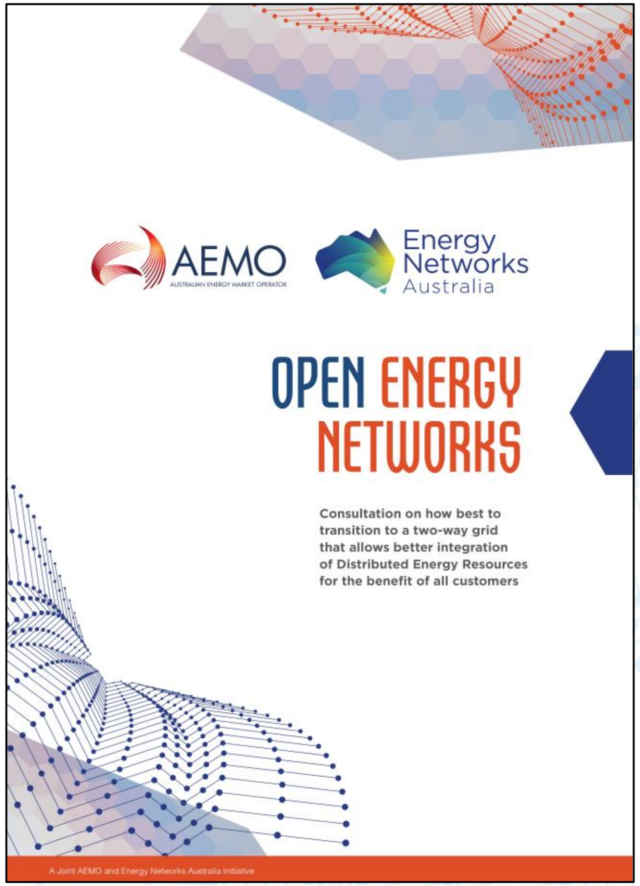
Evolution





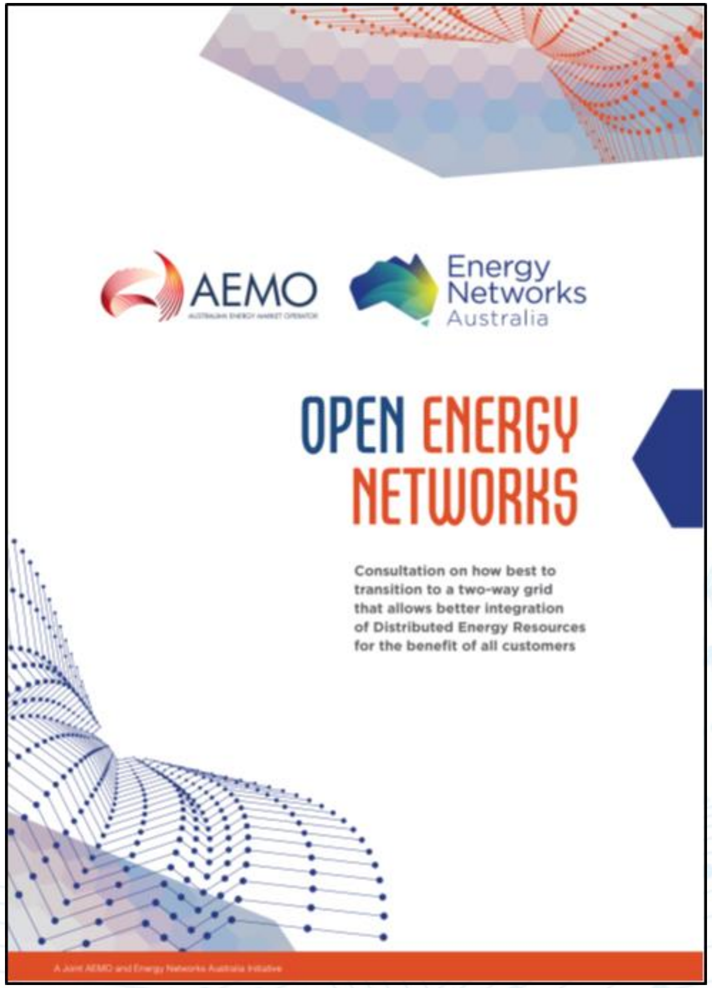
The Roadmap identified that if DER could be optimised and coordinated properly across the system, significant value could be released for all stakeholders

“Open Energy Networks” - Purpose

- The purpose of this project is to work with all stakeholders on how to best facilitate the entry of DER into the market and creates value for all customers

- Our objective is to identify the:

  1. Technical system requirements and
  2. Accompanying regulatory framework
     - that must be developed for the optimisation of DER connected to the distribution system, in order to
     - reduce barriers for entry into the system and best facilitate innovation and competition that releases value to all customers.



Key principles

1. Simplicity, transparency and adaptability of the system to new technologies
2. Supporting affordability whilst maintaining security and reliability of the energy system
3. Ensuring the optimal customer outcomes and value across short, medium and long-term horizons – both for those with and without their own DER
4. Minimising duplication of functionality where possible and utilising existing governance structures without limiting innovation
5. Promoting competition in the provision and aggregation of DER, technology neutrality and reducing barriers to entry across the NEM and WEM
6. Promoting information transparency and price signals that encourage efficient investment and operational decisions
7. Greatest benefit at minimum cost.

Issues raised in previous OpEN workshops

In Scope

- Are there privacy issues associated with sharing DSO network constraint data?
- Should DNSP as DSO also settle local markets?
- Should Distributed Optimisation be NEMDE like or Nodal pricing ?
- Who clears bids for Wholesale and FCAS when iDSO or DNSP is DSO?
- Should DER be able to "double dip" wholes and network services ?
- Latency of communications may affect ability of DER to bid and dispatch, how best to design to allow for autonomous operation?
- Who manages Reserve Contracts for DER?
- Should others have access to DER register – i.e. Retailer/Aggregator?
- LV network – limited visibility and mixed DER penetrations
- Priority for Dispatch Network v Wholesale
- DER Asset Management – who manages the process when customers churn retailers?
- Who pays for Network Support services?

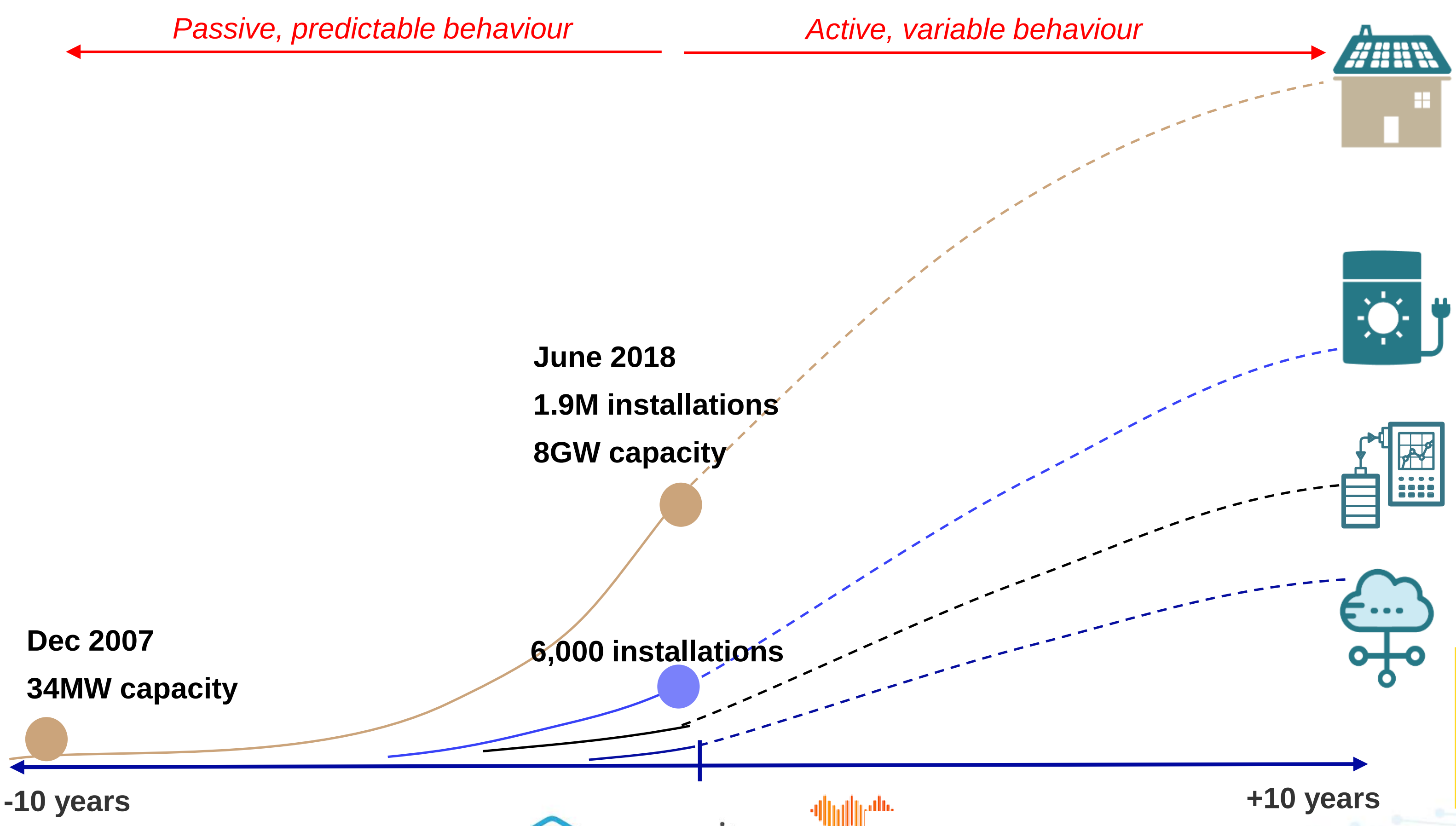
Out of Scope

- Can DER help manage Value of Customer Reliability ?
- Consumer Equity – share DER benefits
- Should DER have firm access or should it be pay to play?
- Who defines DER device cyber security settings?
- What is role of Tariffs/Pricing signals?
- Aggregator vs Retailer – what are the differences, NER considerations?
- How is the Market going to define aggregations – what MW threshold is appropriate?
- What is the role of TNSP?
- Inverter Technical Settings – how best to ensure voltage and system security are managed
- What is the role of Manufacturer and Installer of DER in the Market?
- Is their a more Consumer Centric model that can be adopted in Distribution market?
- What about loss factors – DLF/MLF?
- What are the customer rights with respect to Aggregator contracts?

Session 1

Required Capabilities and Actions

Distributed Energy Resources (DER) are growing in numbers and capacity. They are also becoming smarter



Roof Top PV

- Initially growth spurred by generous feed-in tariffs
- Sustained growth through lower cost and rising electricity prices
- Average system size growing to 6kW

Home batteries

- Sparked by retirement of feed-in tariffs
- Sustained through product bundling with solar PV

Local Energy Management Systems

- Consumers adopt new technologies adding value for individual systems by improving PV system performance and optimising charging discharging times

Aggregators

- Seek to monetise value from additional network services

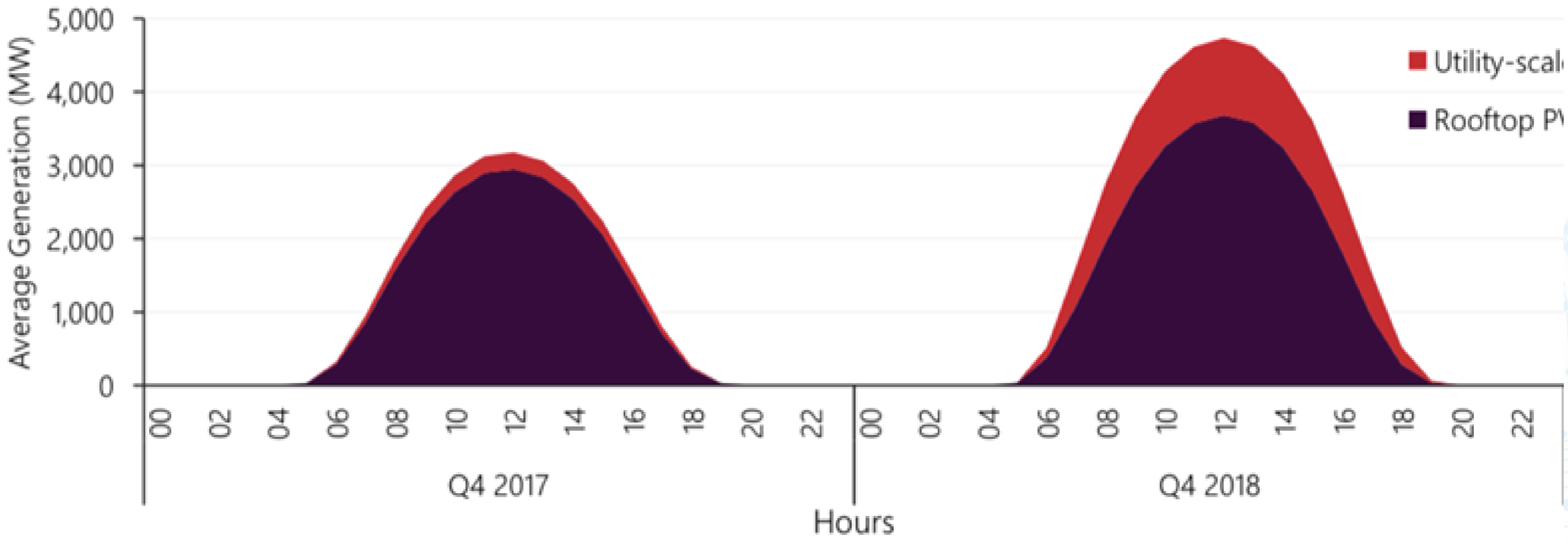
reposit

solar analytics

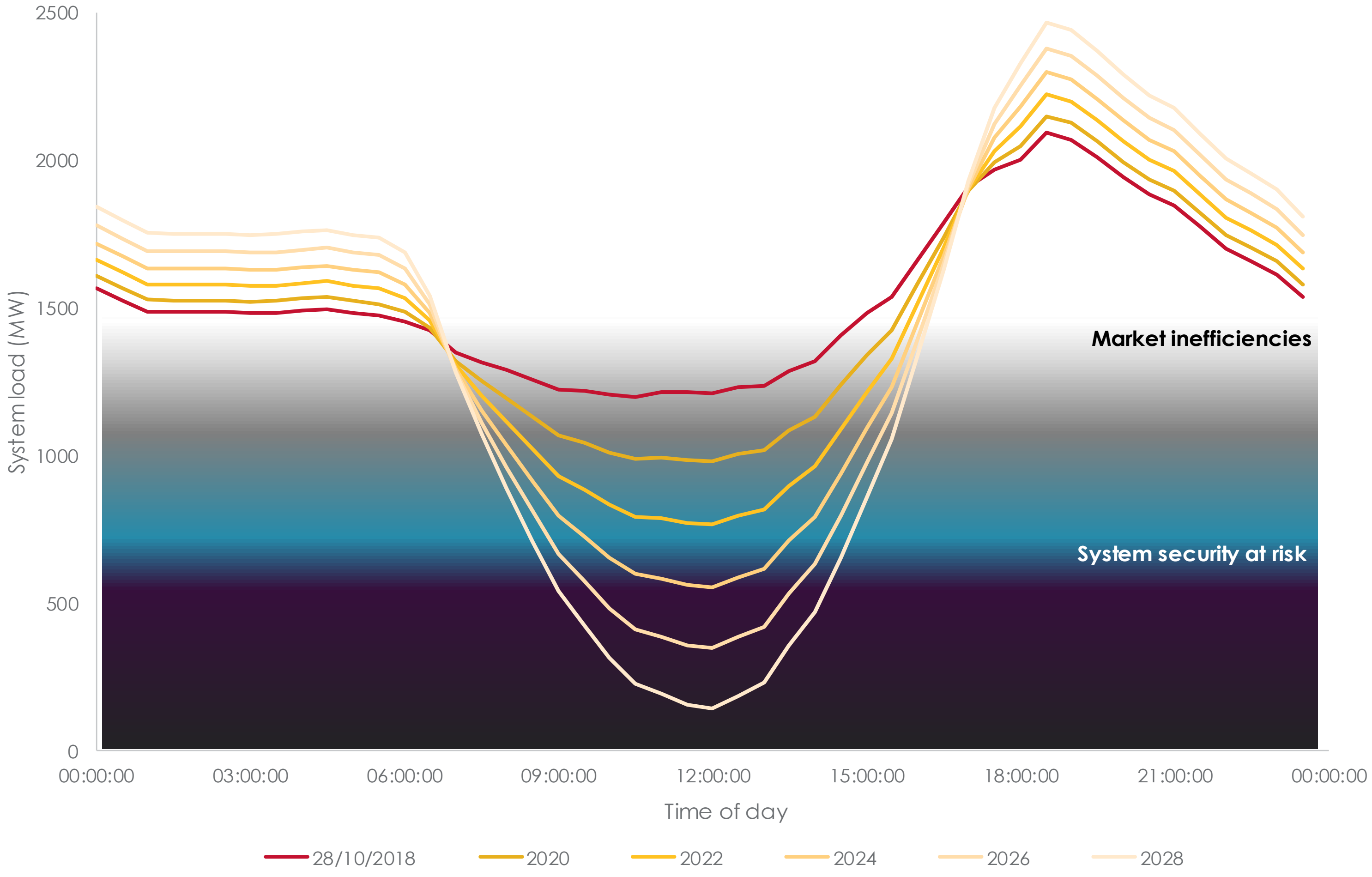
switchDin

Source: APVI, Clean Energy Regulator

Average NEM hourly large-scale solar and rooftop generation profile across Q4 2017 and Q4 2018



PV forecasts continue to increase, bringing closer system risks…

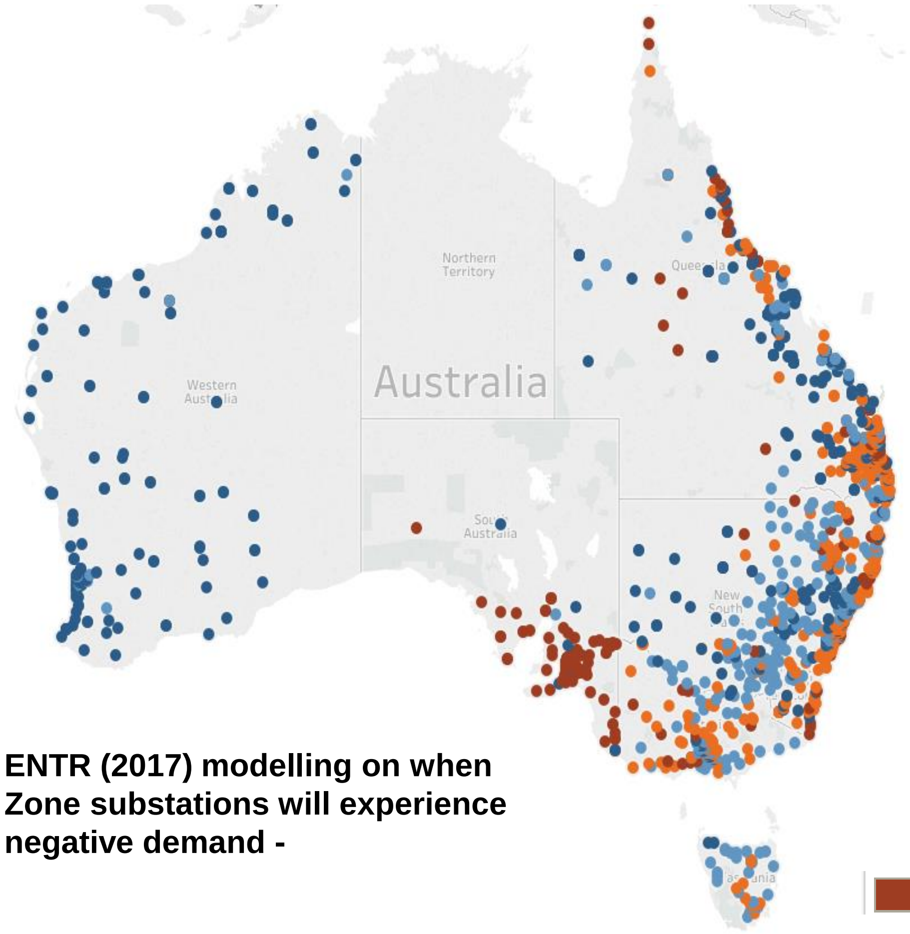


AEMO's WEM analysis on the shape of the load curve on the minimum demand day, 2018 actuals forecast to 2028, based on a persistence PV forecast

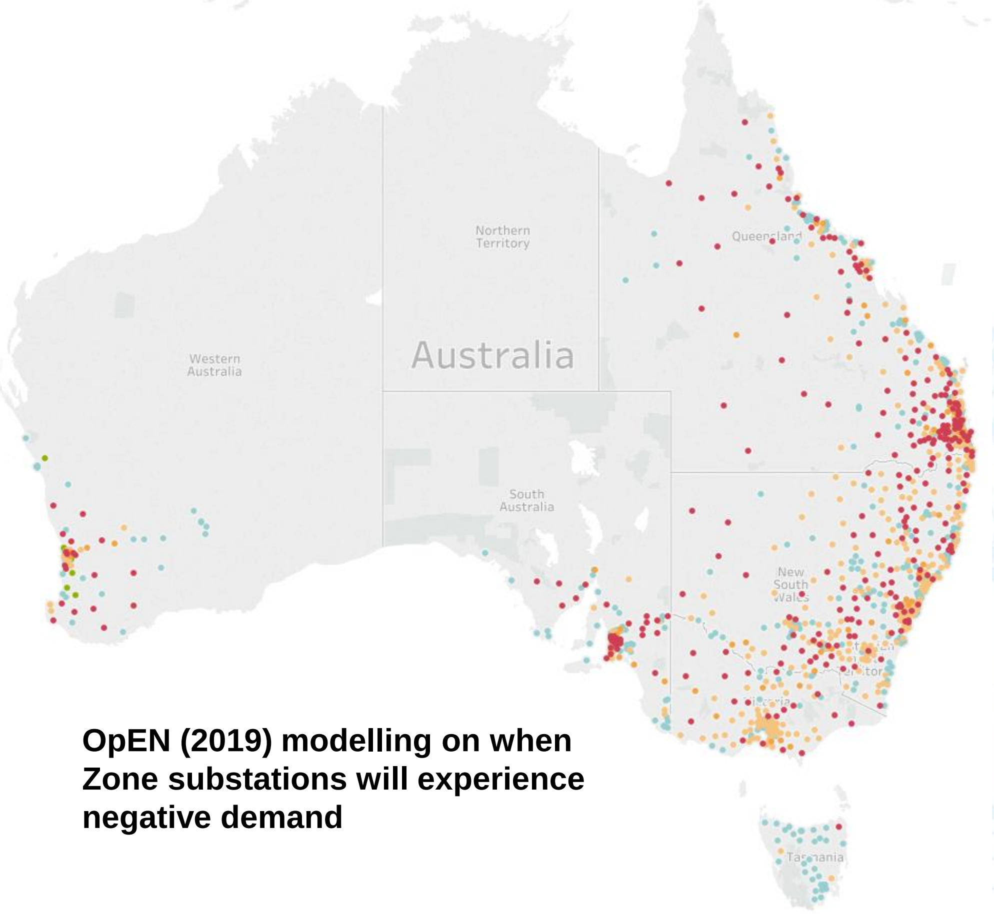
ESOO PV uptake forecasts suggested minimum demand of 500MW in 2028

Regional Modelling: Distributed energy resources adoption

Within the next few years, whole regions of Australia's electricity system must be capable of operating securely, reliably and efficiently with 100% or more of instantaneous demand met from distributed energy resources



ENTR (2017) modelling on when Zone substations will experience negative demand -



OpEN (2019) modelling on when Zone substations will experience negative demand

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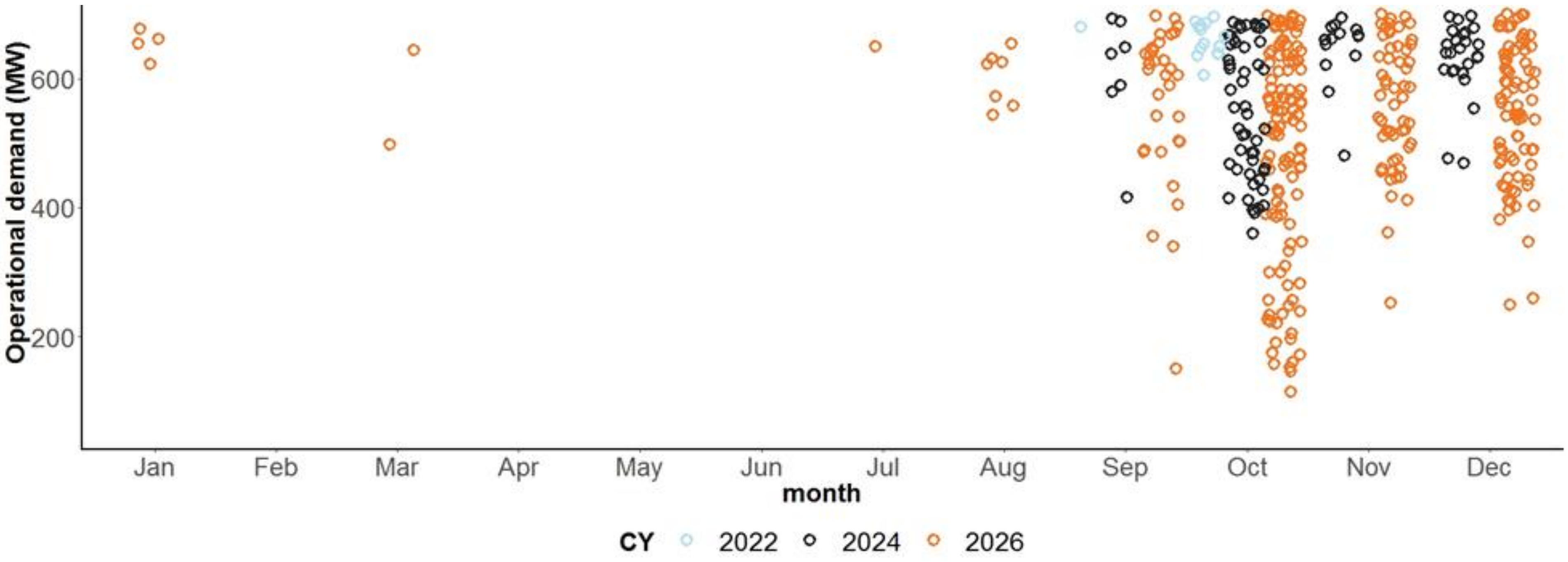
System security risks cluster around spring and early summer…

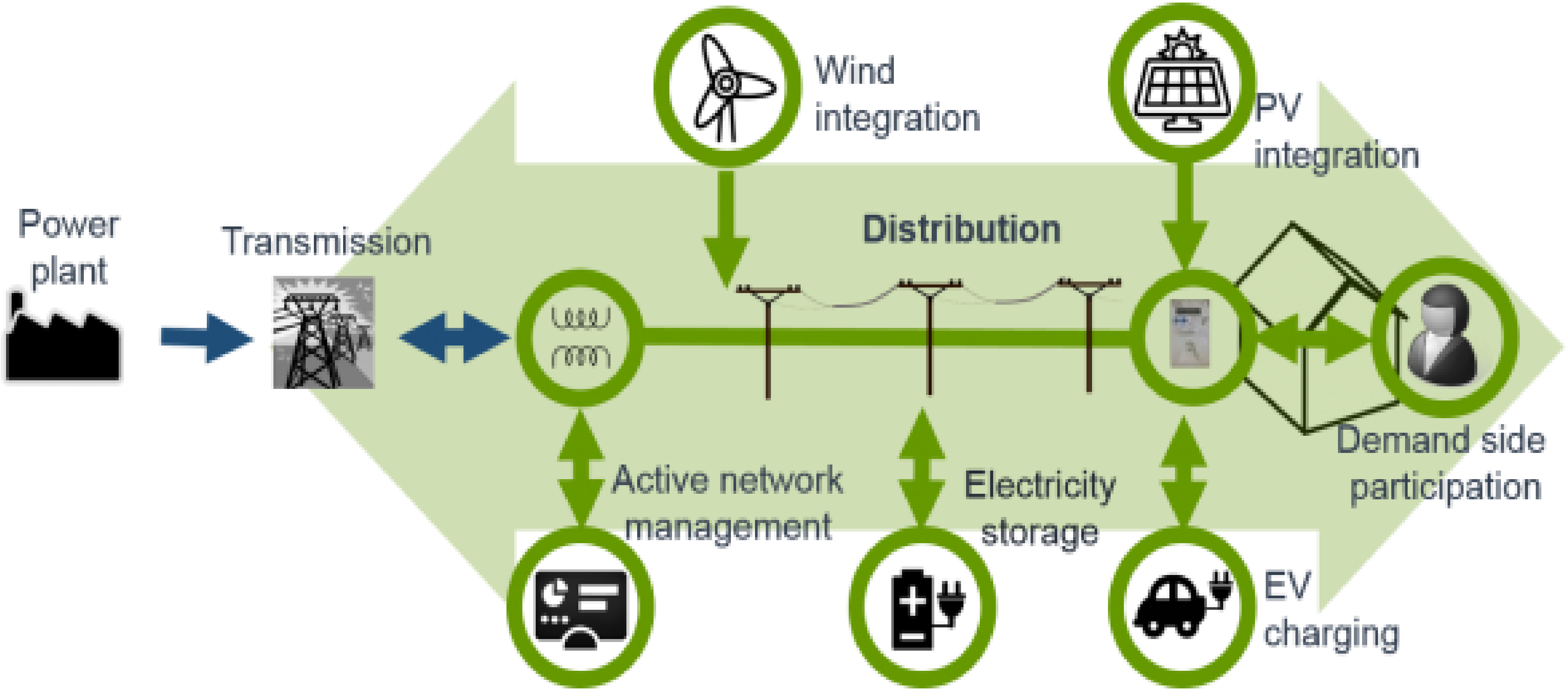


WEM: AEMO prediction of distribution of system security risks across a year: events in each month

System security risks fall into four categories…

	Description	Exposure and Timing	Risk
Behaviour during disturbances	DER may disconnect or cease generation following power system disturbances.	Already aggregate behaviour of Solar PV is visible during power system events. Standards and connection agreements need to be updated to address issues	High
Dispatchability	There is no technical pathway to actively manage distributed Solar PV in the system	2020s However, the aggregated Solar PV capacity in the NEM is already larger than the largest generator.	High
Emergency Frequency Control Schemes	UFLS becoming less effective as Solar PV penetration increases	Already an issue in high Solar PV output periods in Distribution Network.	High
System Restart	SRAS provided by large, synchronous units, but requires stable load. Solar PV can reduce load available.	May be periods where inadequate load is available, further analysis required.	Medium

The evolved electricity system

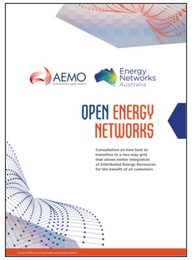


In the evolved electricity system, electricity can flow in a bi-directional manner, that is, flowing to consumers connected to the distribution network, or from the distribution network to the transmission network when generation from DER sources connected to the distribution exceeds customer demand in specific suburbs or substations.

Required Capabilities – what?

Smart Grid Architecture Modelling

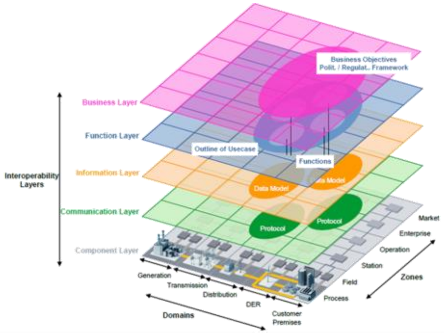
Further development of industry preferred market models through a series of industry workshops with consideration of additional functions and processes required for DSO.



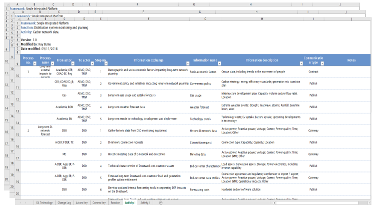
Open Energy Networks Consultation Paper (2018)

Consulted industry on commercial principles to promote flexibility markets and potential market models.

SGAM



Future Worlds (metamodel) Consultation



The Smart Grid Architecture Model (SGAM) methodology is a way to represent a complex electricity system and break it down into is individual parts. It is three dimensional which allows complex aspects of the electrical network to be considered from a variety of perspectives

Required Capabilities and a Hybrid Model

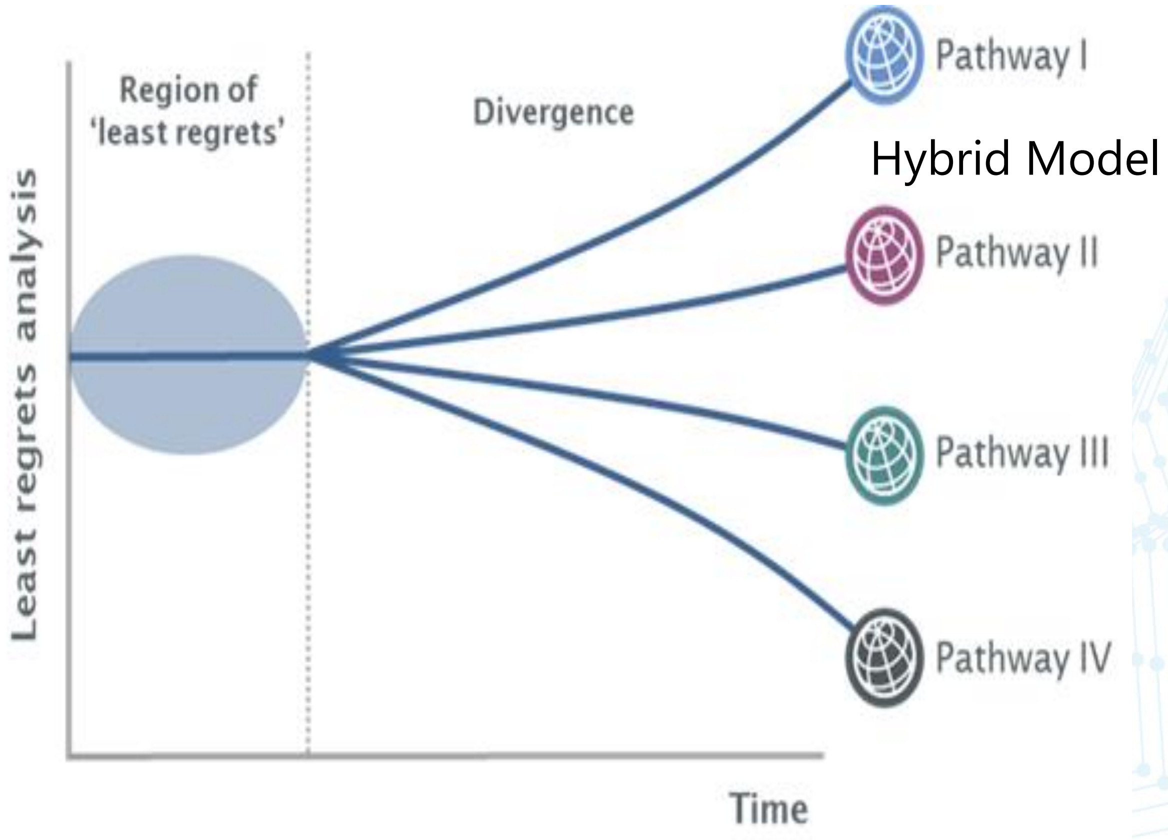
Least regrets approach

The least regrets analysis explores the four framework pathways the electricity system may travel down to progress towards a DSO optimisation.

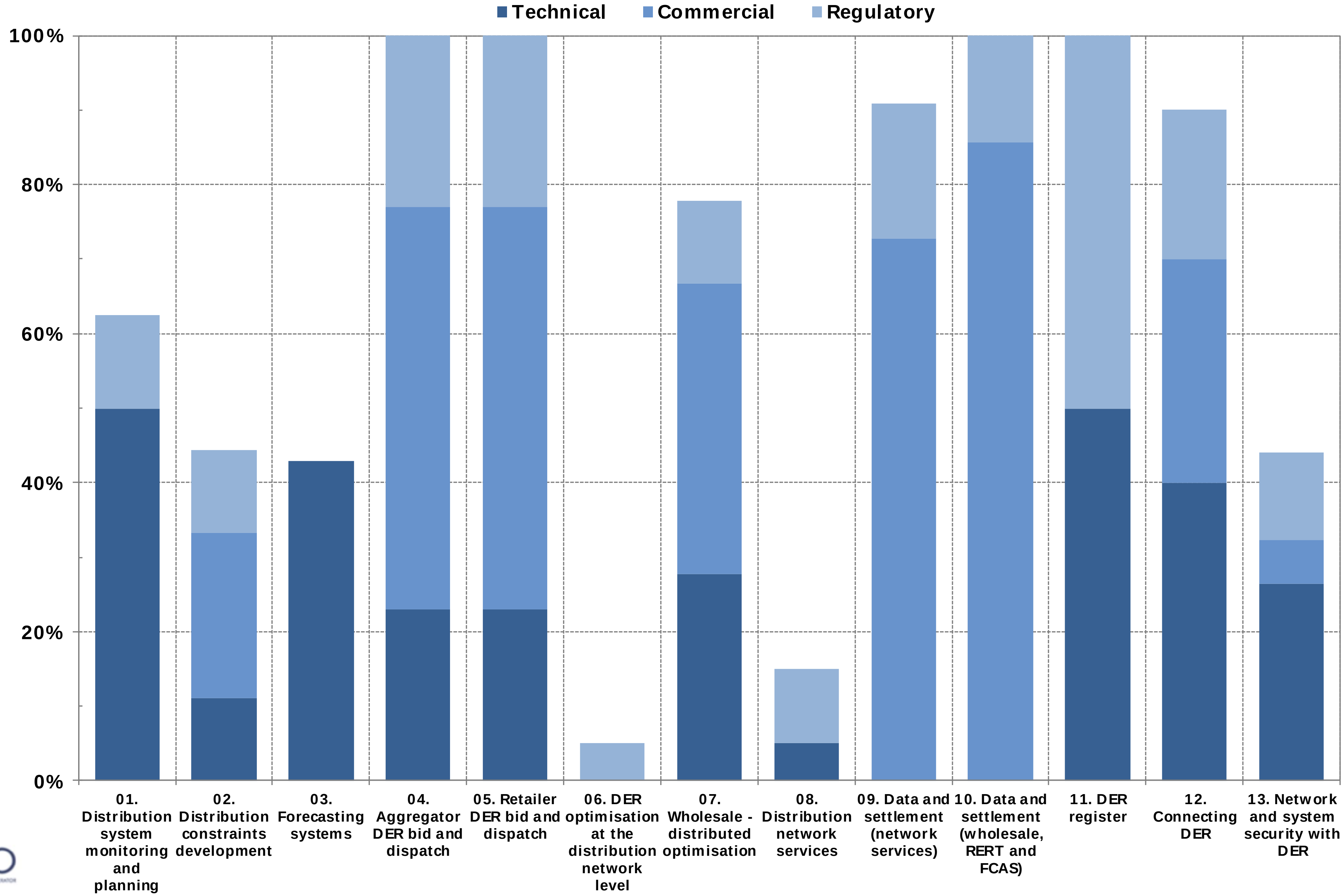
Least regret actions exist at the convergence of the four frameworks where commonality is present across them.

Least regret actions can be implemented over the short term, irrespective of the ultimate pathway that actually manifests with:

- Minimal risk of additional work requirements;
- Investments being sunk;
- Or value not being realised.



Commonality across functions by functional area



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First Order Required Capabilities:

These are critical actions that must be undertaken to manage the current issues associated with DER Integration and will be required to support any of the model frameworks

MILESTONE 1: DNSPs define network visibility requirements and network export constraints

- Define DNSP requirements for increased network visibility to maintain network operations within required parameters
- Define how to achieve increased network visibility to maintain network operations within required parameters (operating envelopes)
- Establish an iterative and targeted approach for the timing of investments required to provide network visibility to maintain network operations within required parameters

MILESTONE 2: DNSPs define communication requirements for operating envelopes

- Define protocols for operating envelope communication
- Establish a Australian standards and/or guidelines to support the establishment of operating envelopes
- Define data access permissions

MILESTONE 3: DNSPs establish industry guideline for operating envelopes for export limits

- Develop an Industry guideline that outlines the requirements and use of operating envelopes

MILESTONE 1: DNSPs define network visibility requirements and network export constraints

Define DNSP requirements for increased network visibility to maintain network operations within required parameters

- » Establish what information is required
- » Establish what time frames data is required
- » Establish where the data needs to come from

Define how to achieve increased network visibility to maintain network operations within required parameters (operating envelopes)

- » Define minimum technical requirements and system specifications for enhanced visibility, communication and co-ordination between the DER and DNSP/DSO
- » Define new operating envelopes for export limits stablish new minimum technical requirements for information, data and communication architecture

Establish an iterative and targeted approach for the timing of investments required to provide network visibility to maintain network operations within required parameters

- » Evaluate if customer losses are likely to outweigh network costs and therefore scope the case for a future network project
- » Define methodology of obtaining operating envelopes for network data
- » Review current methodology for calculation operating envelopes for export limits
- » Establish the methodology to calculate network constraints and develop the operating envelope from the technical network data.

Milestone 2:
DNSPs define communication requirements for operating envelopes

Define protocols for operating envelope communication

- Determine the appropriate format (e.g. syntax, semantics) of the data and its transmission method
- Establish agreement across all industry stakeholders regarding the form of data and systems

Establish a Australian standards and/or guidelines to support the establishment of operating envelopes

- Develop or adopt an Australian Standard on data management frameworks/protocols
- Develop or adopt an Australian Standard on communication protocols/frameworks
- Develop or adopt an Australian Standard on cyber security
- Develop or adopt an Australian Standard on control system protocols
- Develop or adopt an Australian Standard on interoperability

Define data access permissions

- Establish agreement across all industry stakeholders regarding access arrangements to data and systems

Milestone 3:

DNSPs establish industry guideline for operating envelopes for export limits

Develop an Industry guideline that outlines the requirements and use of operating envelopes

- Establish an agreed framework and principles for Australian Network Service Providers to for identification of network constraints, the establishment and communication of operating envelopes
- Establish an industry guideline for operating envelopes based on the agreed framework and principles and the technical requirements identified in Milestones 1 and 2.

Required Capabilities: an iterative and targeted approach

- The Open Energy Networks project agrees that the frameworks for DER optimisation will be rolled out in a targeted way.

- Network monitoring and Operating Envelope calculation and communication will be needed as a required capability for all networks to determine hosting capacity.

	Low Hosting Capacity (<20%)	Medium Hosting Capacity (20% - 40%)	High Hosting Capacity (>40%)
DER Low < 20%	Monitor	Operate (as today)	Operate (as today)
DER Medium 20% - 40%	Optimise	Monitor	Operate (as today)
DER High>40%	Optimise	Optimise	Monitor

- Initially operating enveloped may be deterministic and static, but in order to optimise DER in the network, technical and market operators will require increasingly dynamic (system and local) envelopes


3500
3000
2500
2000
1500
1000
500
0
NPV A$m
Low
High
South Australia (hosting constraint only) 2035
Great Britain (full integration) 2030
ENTR with $600m cost assumed (full integration) 2030

2nd Order Actions & Trials

Common areas for action

Priority Area	Recommendation to be enacted	Description
Aggregator development	Define the aggregator role	Clarification around the role the aggregator will play in the DER optimisation and its relationship with the energy retailer is required
	Aggregator and energy retailer coordinate to develop portfolios of customers	Aggregators and energy retailers can begin to further engage with active DER customers to develop a range of services that it may offer the network or market operators.

Service description				Supply side						Demand side		
				Centralised generation		Transfer within regions	Stabilising devices			Load	Decentralised resources	
System Attribute	Requirement	Service	Spatial level of need	Synchronous generator	Non-synchronous generator	Transmission and distribution networks	Grid reactor, grid capacitor, static VAR compensator	Static synchronous compensator	Synchronous condenser [1]	Large industrial, residential, commercial	Solar PV	Battery storage
Resource adequacy	*Provision of sufficient supply to match demand from customers*	Bulk energy	System wide	●	●	→	○	○	○	●	●	●
		Strategic reserves	System wide	● [2a]	◐ [3a]	→	○	○	○	●	◐ [3b]	◐ [3b]
	Capability to respond to large continuing changes in energy requirements	Operating reserves	System wide	● [2b]	◐ [3a]	→	○	○	○	●	◐ [3b]	◐ [3b]
	Services to transport energy generated to customers	Transmission & distribution services	Local	● [4]	● [4]	●	●	●	●	● [4]	◐	◐
Frequency management	*Ability to set frequency*	Grid formation	Regional	●	◐ [5]	●	○	○	○	○	○	◐ [5]
	Maintain frequency within limits	Inertial response	Regional	●	◐ [6]	→	○	◐ [7]	●	○ [8]	○	◐ [6]
		Primary frequency control	Regional	●	● [9]	→	○	○	○	●	●	● [9]
		Secondary frequency control	Regional	●	● [9]	→	○	○	○	●	●	● [9]
		Tertiary frequency control	Regional	●	● [9]	→	○	○	○	●	●	● [9]
Voltage management	*Maintain voltages within limits*	Fast response voltage control	Local	●	●	○	●	●	●	●	◐	●
		Slow response voltage control	Local	●	●	○	●	●	●	●	◐	●
		System strength	Local	●	○	→	○	○	●	○	○	○
System restoration	*Ability to restore the system*	System restart services	Local	●	◐ [10]	→	○	○	○	○	○	◐ [10]
		Load restoration	Local	●	●	⇨	●	●	●	●	◐	◐

AEMO Predicts that DER will be able to provide a number of technical services – although further work needs to be done to understand the characteristics of the services offered by DER.

1 This includes generators with ability to operate in synchronous condenser mode.
2a While many synchronous generators can provide energy reserves, some less firm technologies (solar thermal or pumped hydro storage) will be limited by the amount of energy storage they include.
2b While many synchronous generators can provide flexibility services, coal generators are limited in their ability to provide such services.
3a Limited by duration for which service can be delivered.
3b Limited by duration for which service can be delivered; existing controllability is limited.
4 The provision of local voltage support from generators and loads can improve the network transport capability near their respective connection points.
5 Grid forming power electronic converters are available and have been proven on small power systems. Development of grid forming converters for large power systems is an emerging area of international research.
6 Some fast frequency response capabilities can provide emulated inertia response, but are not yet proven as a total replacement for synchronous inertia.
7 Static synchronous compensators with energy storage devices are being trialled as an emerging provider of inertial response.
8 Except for load relief.
9 Includes fast frequency response capabilities.
10 System restoration services from variable non-synchronous generators is an emerging area of international research. If they are grid scale, batteries are likely to provide some system restoration support.

Ability to provide service		
● Fully capable	◐ Partial or	○ Unable
→ Enables delivery	⇨ Partial or limited delivery	

Note: Classifications are indicative of the general ability of each technology type. The extent to which technologies can provide each service must be assessed on the specifics of each individual system.

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Common areas for action

Priority Area	Recommendation to be enacted	Description
Collaboration for network forecasting and development	Aggregators, energy retailers and transmission customers forecast the long-term and short-term load and generation profiles of their customers	Aggregators and energy retailers have responsibility to provide to network and market operators granular load and generation profiles for their customers, both long-term trends and projections and short-term forecasts based on network and customer status
	D-network, T-network and joint system investment plans are created	An extension of business as usual investment planning with greater emphasis on joint planning and requiring cost-benefit analysis of the use of network services vs traditional investment routes. Update the ISP to include both Distribution and Transmission Network investment recommendations.

Possible Key actions to Trial

Priority Area	Recommendation to trial	Description
Wholesale market for DER integration	Aggregator and energy retailer apply to participate in the wholesale and FCAS services markets	All of the frameworks anticipate that DER, or aggregated portfolios of DER, will participate as a Market Ancillary Services provider, Market Customer or Market Generator.
	Aggregator and energy retailer dispatch customers in response to market signals or contractual arrangements	The creation of communication infrastructure between aggregators, energy retailers and the market platform to facilitate the use of real-time dispatch signals is needed to unlock DER value A framework for dispatch at a Wholesale and Local Level will need to be developed including standard communication protocols and a common bidding process and common infrastructure that can be then transposed by Aggregators/Retailers to send signals to DER.

Possible Key actions to Trial

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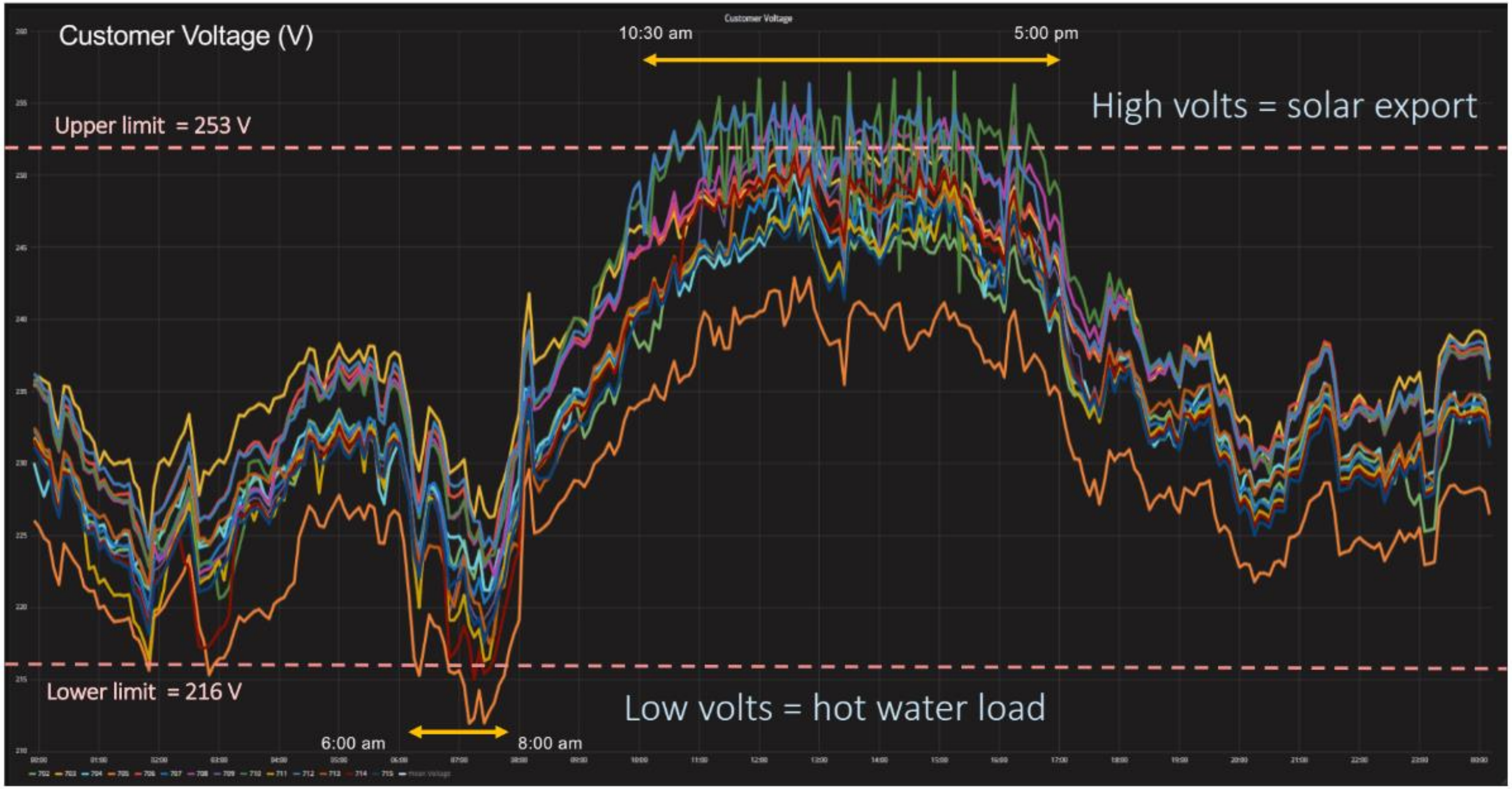
Possible Key actions to Trial

Priority Area	Recommendation to trial	Description
Network services market for DER integration	Adjust market rules to establish a network services market	A trial area for a distribution network services market could be established: to gauge the costs and benefits such a market would bring; to better understand the appetites of customers, aggregators, energy retailers and network operators to participate; and to determine best practice going forward
	Rules or guidance is created on the use of bilateral network services contracts out with the market platforms	Bilateral contracts for network service must be coordinated with market operations and rules established setting out any exclusions on the use of bilateral contracts out with an optimised market platform

Network Voltage – how to value reactive power?

Customer Voltage (V)



Time (hh:mm)

Networks Renewed: AusNet

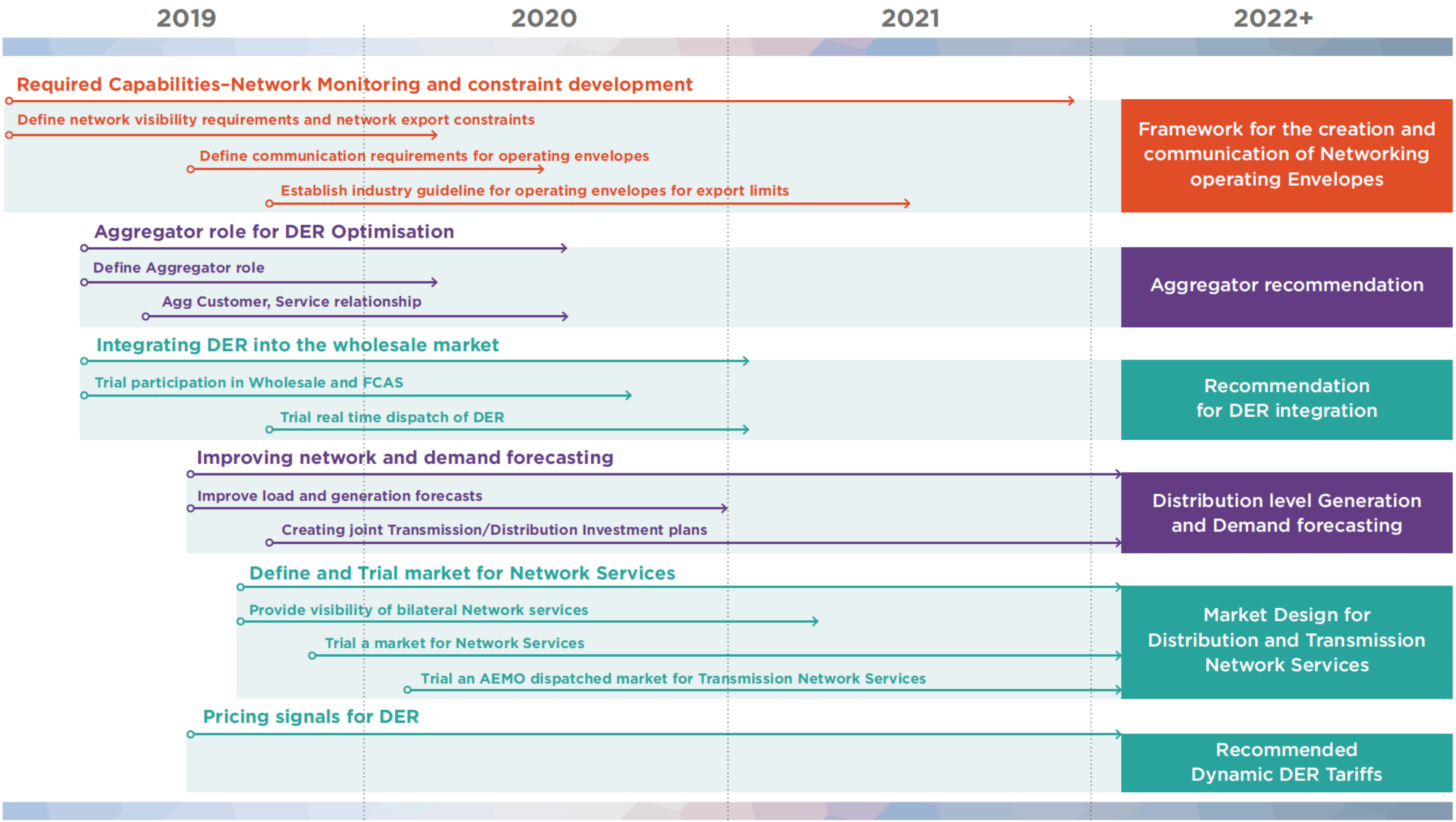
Possible Key actions to Trial

Priority Area	Recommendation to trial	Description
Network services market for transmission customers	AEMO dispatches the T-NSCAS, wholesale and FCAS services markets	AEMO may play a role in actively managing T-network constraints by trailing a network services market open to transmission customers

Possible Key actions to Trial

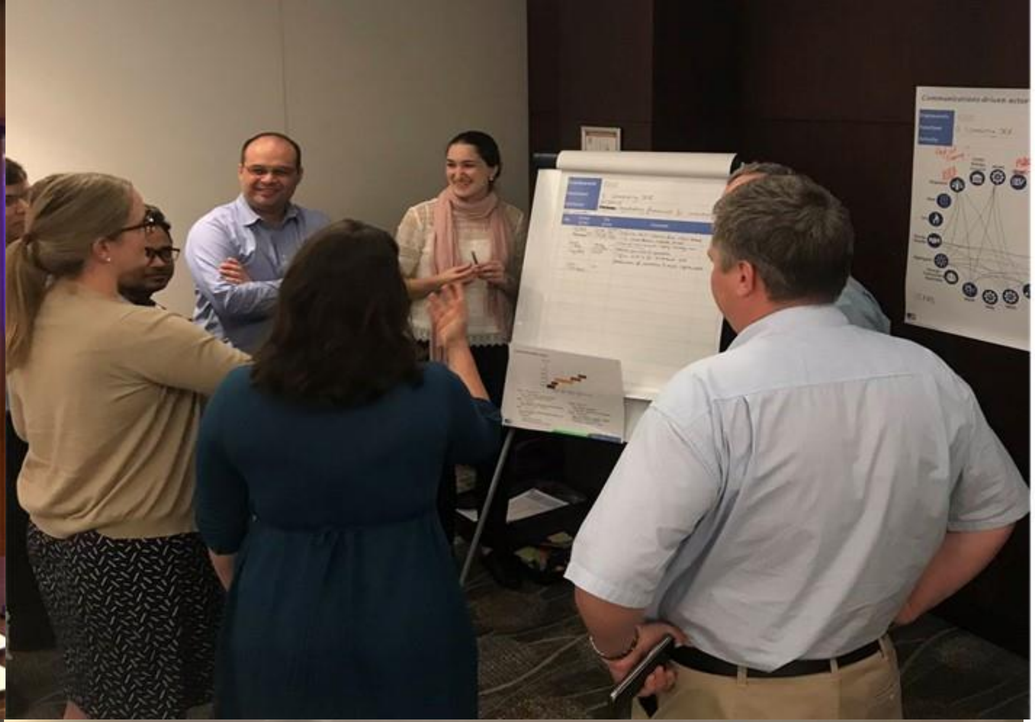
Priority Area	Recommendation to trial	Description
Pricing signals	Pricing signals	Local pricing signals can be developed to manage customer behaviour out with a market or contractual obligation. Signals can be market driven (i.e. based on the wholesale price of electricity), network driven (i.e. based on local constraints for import / export) or a combination of both. Trials may be undertaken to better understand customer response to pricing signals and their position in the transition to a Distributed Market framework

Required Capabilities and Recommendations - Timeline for action



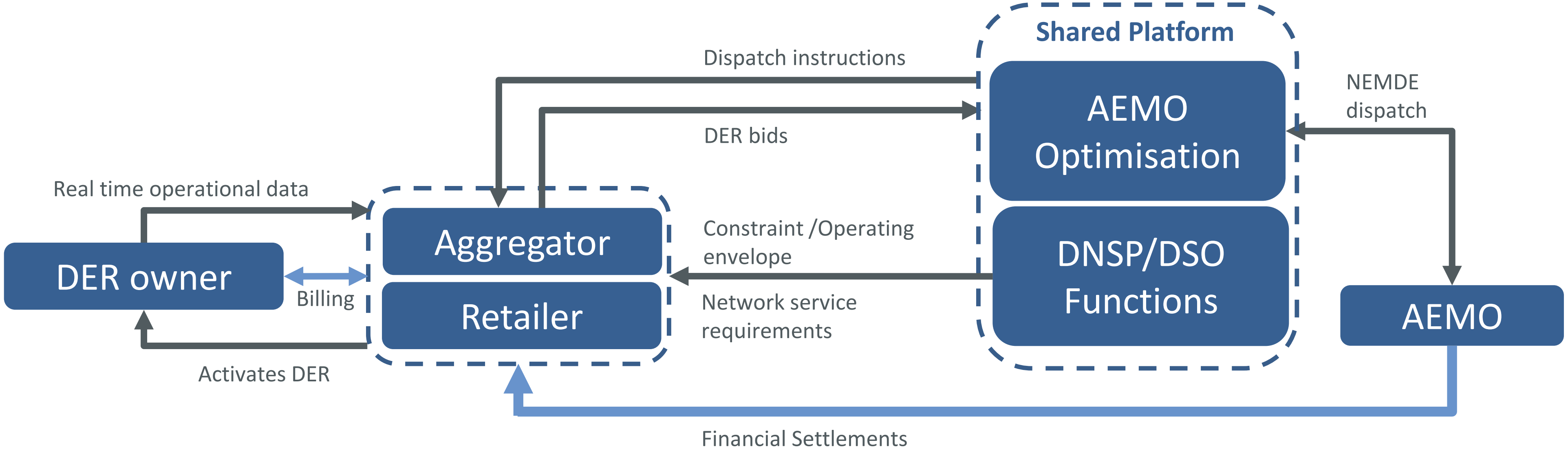
Session 2

4th Model



The 4th framework

Based on feedback from the Consultation, and outcomes from the workshops – the project has identified a fourth Hybrid Model that combines elements of each of the models. This has been included in the SGAM modelling by EA Technology.



A strawman model was developed which placed emphasis on **central optimisation (SIP)** combined with **DSO-DER engagement (TST)** with parts of the **iDSO.**

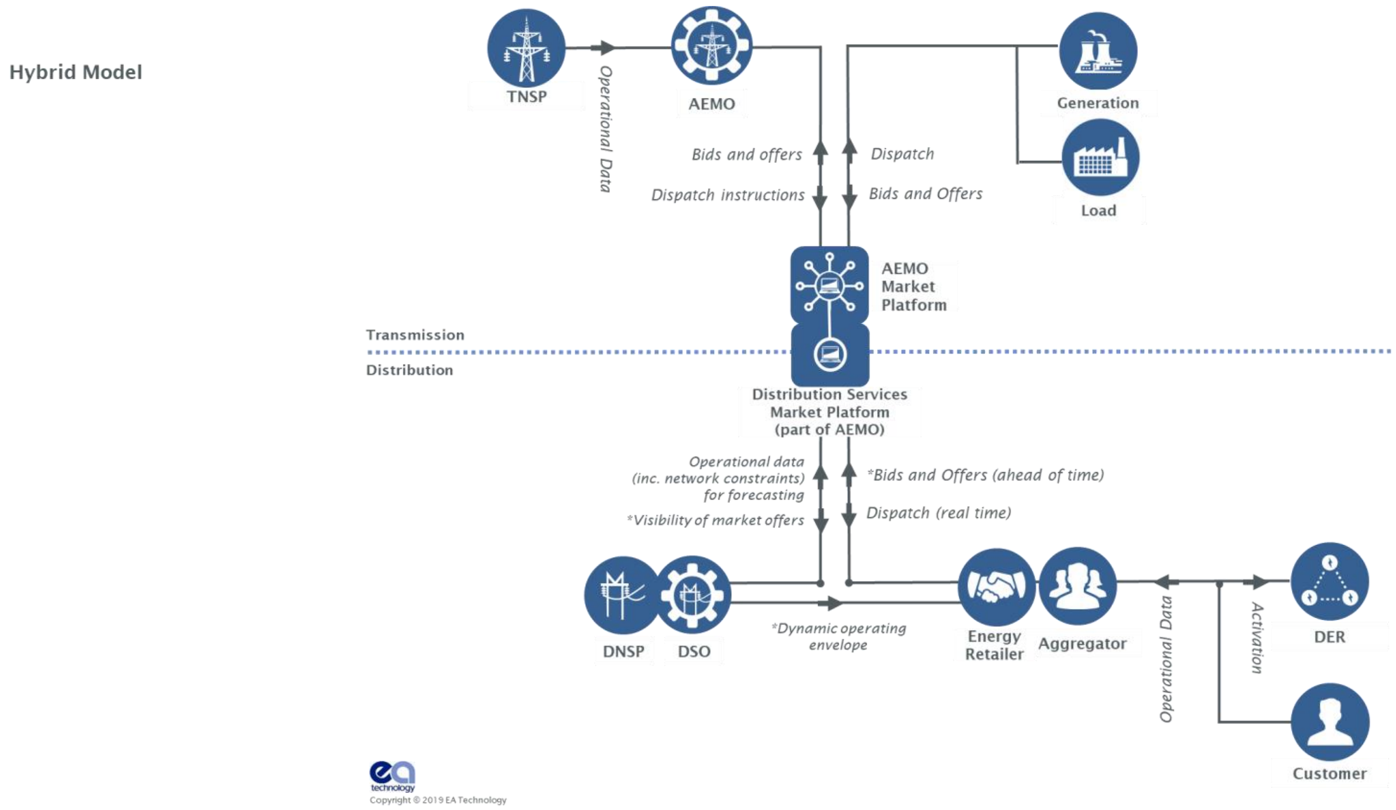
This strawman model was then actualised by testing against the 13 SIP and TST functions to produce the hybrid framework.

Hybrid Model

- AEMO manages market platforms that ensure efficient and effective operation through shared data and information streams, and coordinated functionality
- DSO manages the network and publishes network constraints and requirement for network services

A key component is the expanded "network services" market that enables economically efficient localised DER-related support for optimised primary market activities

(e.g. VAR support to alleviate local network binding voltage constraints)



Session 3

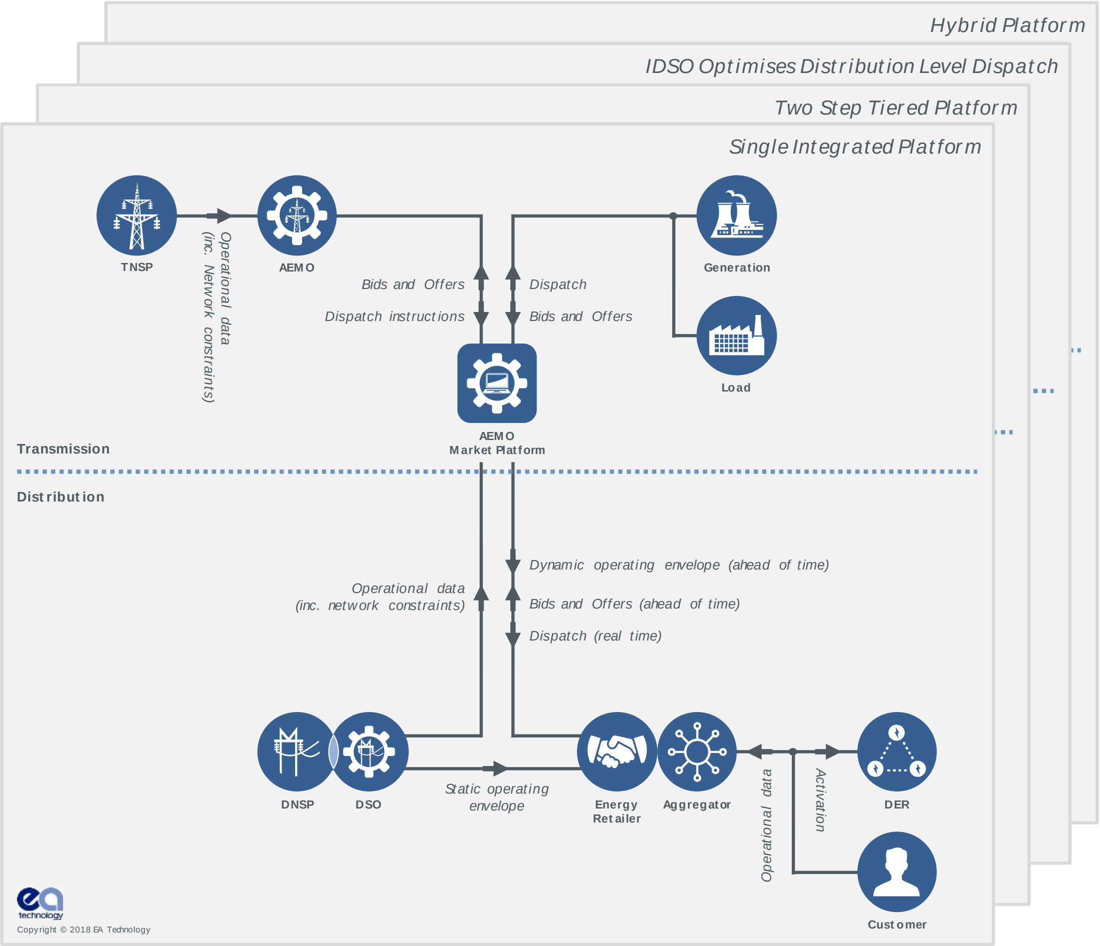
Market model framework modelling

https://www.energynetworks.com.au/models

Contents

1. THE FOUR DER OPTIMISATION FRAMEWORKS

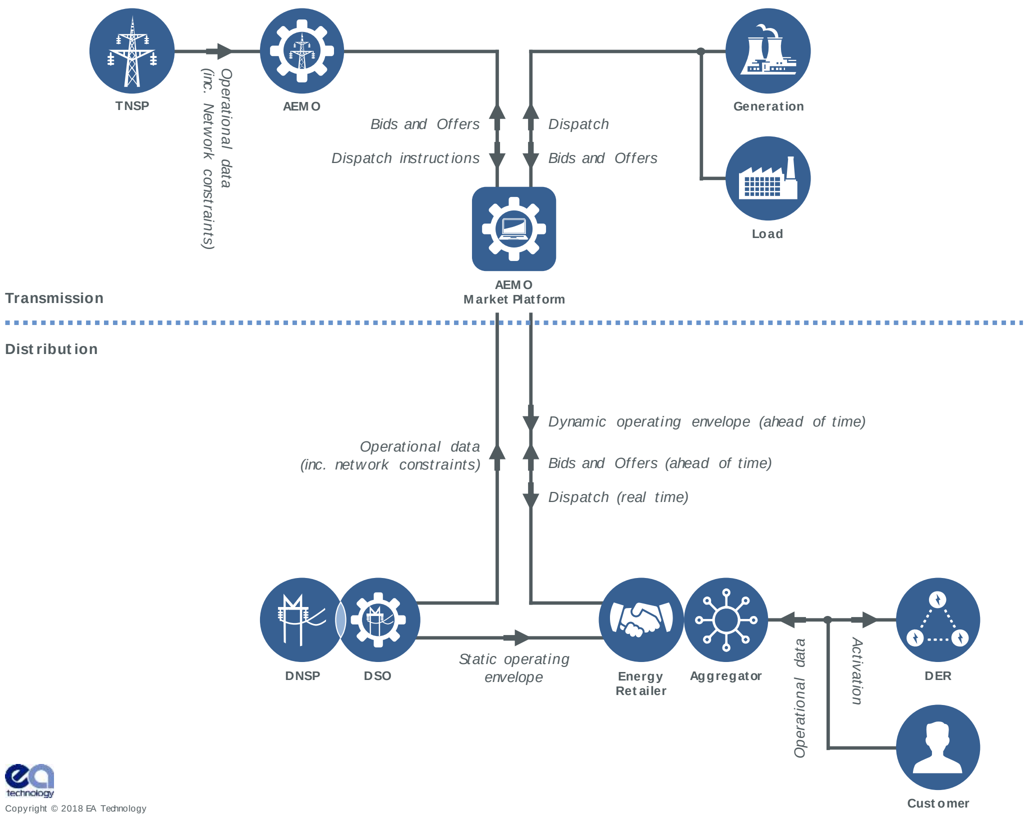
Distribution Level Optimisation frameworks



- Four distribution level frameworks have been developed by the OpEN-PRJ to facilitate the transition of DNSPs to DSOs.
- The frameworks broadly cover:
  - how the DSO accesses DER and the associated market arrangements;
  - how DER provides services to networks and markets
  - the extent of the DSO's relationship with AEMO

Single Integrated Platform framework

Key actors and interactions

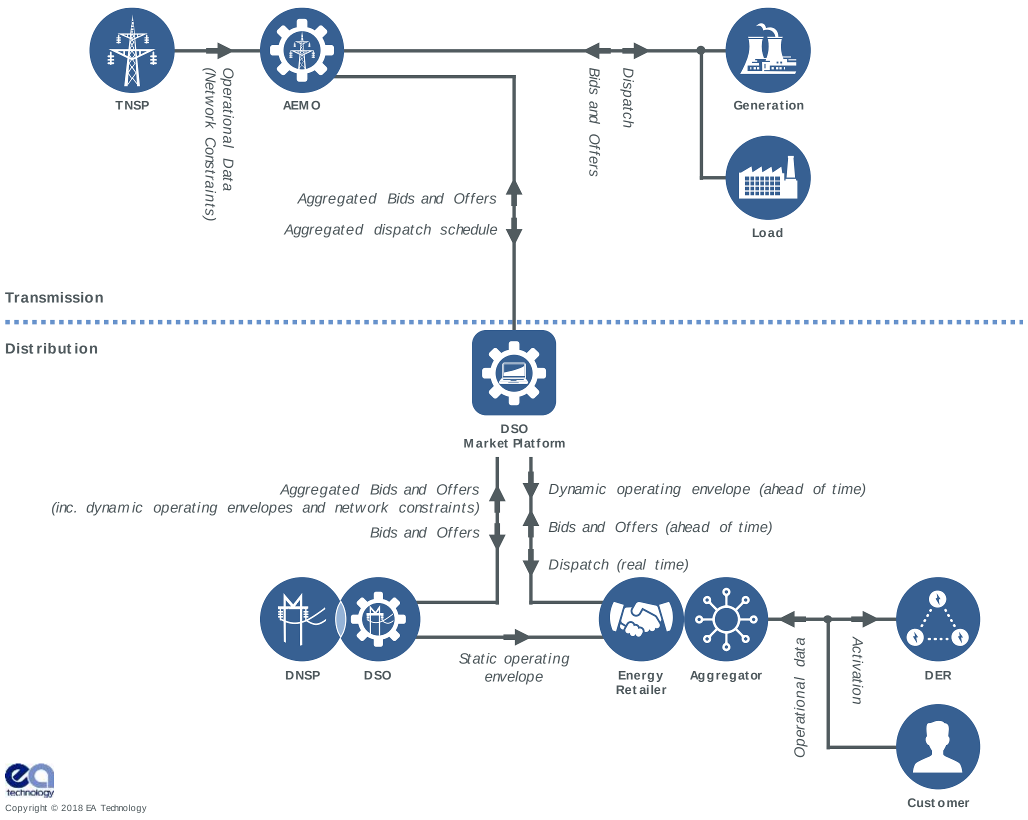


Key characteristics

Market arrangements	• There is a single central market comprised of wholesale and ancillary services markets (i.e. FCAS, NSCAS) that is operated via a central market platform • Market participants, including DER via aggregators/retailers, submit bids and offers for system services to the central market platform which in turn makes them available to AEMO for whole system optimisation
AEMO	• AEMO organises and operates the central market • AEMO assesses all bids and offers and optimises the dispatch of energy resources considering T-network and D-network constraints • AEMO sends out dispatch instructions to energy resources, including DER via their respective Aggregator/Retailer
DSO	• DSO provides DER with static operating envelopes based upon the technical capability forecast of the D-network to accommodate DER dispatch • DSO actively exchanges information with AEMO to facilitate the consideration of D-network constraints and the development of dynamic operating envelopes in the whole system dispatch process
Aggregator / Retailer	• Aggregator/Retailer combines different DER and offer their aggregated output as system services to the central market platform

Two Step Tiered framework

Key actors and interactions

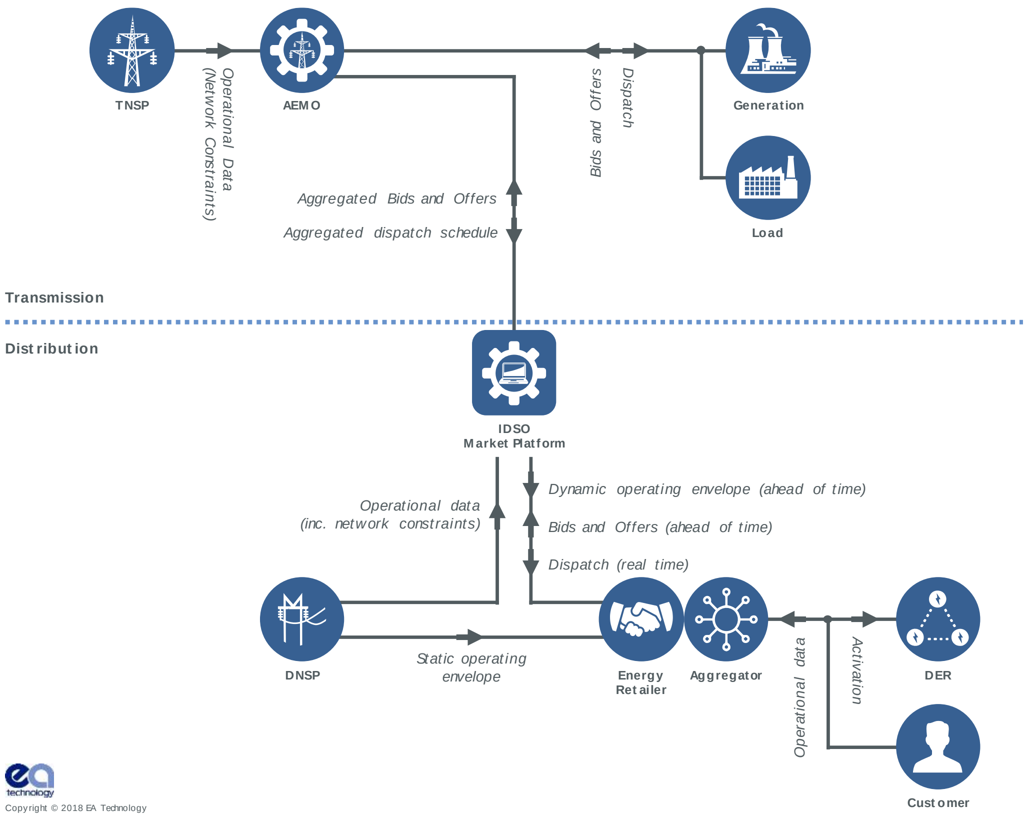


Key characteristics

Market arrangements	• There is a single central market comprised of wholesale and ancillary services markets that is operated by AEMO • There is a local market(s) for regional and national system service provision from DER that is operated via a local market platform
AEMO	• AEMO organises and operates the central market • AEMO assesses all bids and offers and optimises the dispatch of energy resources considering T- and D-network constraints • AEMO sends out dispatch instructions directly to T-network energy resources and indirectly to D-network energy resources via a dispatch scheduled per DER area at the D-network boundary
DSO	• DSO(s) organise and operate the local market(s) • The DSO receives DER bids and offers from the local market, prequalifies them into an aggregated bid stack per transmission connection point based on D-network and DER operating envelopes and passes them to AEMO for whole system optimisation • The DSO allocates the dispatch to individual DER based on the boundary dispatch schedule • The DSO procures, dispatches and settles the DER from aggregators/retailers for D-network constraint management via the local platform

Independent Distribution System Operator framework

Key actors and interactions

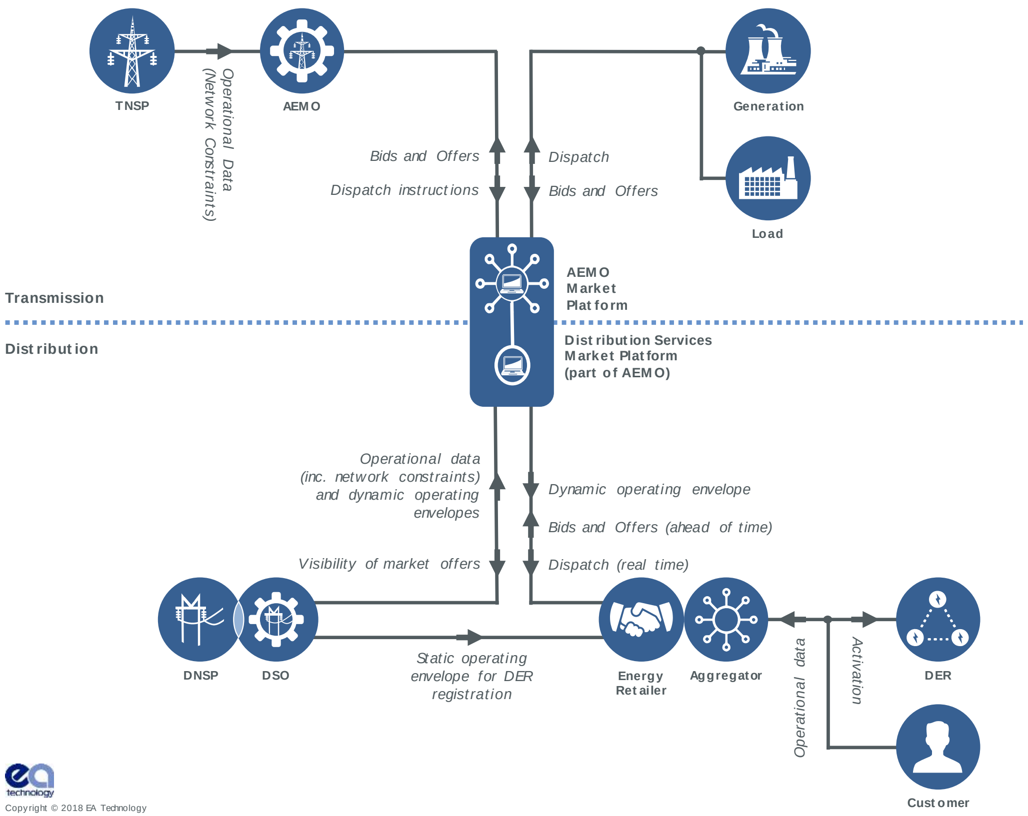


Key characteristics

Market arrangements	• There is a central market comprised of wholesale and ancillary services markets that is operated by AEMO • There is local market(s) for regional and national system service provision from DER that is operated via a local market platform
AEMO	• AEMO organises and operates the central • AEMO assesses all bids and offers and optimises the dispatch of energy resources considering T-network and D-network constraints • AEMO sends out dispatch instructions to energy resources directly or via a dispatch scheduled per DER area at the D-network boundary
IDSO	• IDSO(s) organises and operates the local market(s) • The IDSO(s) receives DER bids and offers from the local market, prequalifies them into an aggregated bid stack per transmission connection point based on D-network and DER operating envelopes and passes them to AEMO for whole system optimisation • The IDSO(s) allocates the dispatch to individual DER based on boundary dispatch schedule
DNSP	• DNSP provides DER with static operating envelopes • DNSP actively exchanges information with the IDSO to facilitate the consideration of D- network constraints and the development of dynamic operating envelopes in the whole system dispatch process

Hybrid framework

Key actors and interactions



Key characteristics

Market arrangements	• There is a two-sided market platform, comprised of wholesale and ancillary services that is organised and operated by AEMO • Market participants, including DER via aggregators/retailers, submit bids and offers for system services to the market platform which in turn makes them available to AEMO for whole system optimisation
AEMO	• AEMO organises and operates the market • AEMO assesses all bids and offers and optimises the dispatch of energy resources considering T-network and D-network constraints • AEMO sends out dispatch instructions to energy resources, including DER via their respective Aggregator/Retailer
DSO	• DSO provides DER with static operating envelopes based upon the technical capability forecast of the D-network to accommodate DER dispatch • The DSO assesses market bids and D-network constraints to generate dynamic operating envelopes for DER which respect distribution network constraints and inform their technical and commercial offering to the markets
Aggregator / Retailer	• Aggregator/Retailer combines different DER and offer their aggregated output as system services to the market platform

Framework comparison

	SIP	TST	IDSO	Hybrid
Advantages	• **Full system orchestration** • Moderate regulatory change • Standardisation of processes and procedures	• DSO/DNSP control DER to actively manage D-network • Potential lower barriers for entry and bespoke arrangements	• IDSO removes perceived conflict of interest • IDSO and DNSP control DER to actively manage D-network	• **Full system orchestration** • *DSO/DNSP and AEMO coordinate D-network requirements (operating envelopes)*
Disadvantages	• *AEMO must interpret D-network requirements* • DSO/DNSP has no direct control over DER	• **Increased coordination required between DSO/DNSP and AEMO** • Perceived conflict of interest for DSO/DNSP • DSO/DSNO has no market operation experience	• New regulated entity • Requires seamless IDSO and DNSP coordination • High coordination required between IDSO and AEMO	• **Increased coordination required between DSO/DNSP and AEMO**

Hybrid Key: **BOLD** – Common to SIP or TST; *Italic* – Enhanced from SIP or TST

2. DEVELOPMENT OF THE DER OPTIMISATION FRAMEWORKS

Functions and activities

The four frameworks were developed around the **13 functions and their associated activities** created by EA Technology in partnership with ENA.

No.	Function
1	Distribution system monitoring and planning
2	Distribution constraints development
3	Forecasting systems
4	Aggregator DER bid and dispatch
5	Retailer DER bid and dispatch
6	DER optimisation at the distribution network level
7	Wholesale - distributed optimisation
8	Distribution network services
9	Data and settlement (network services)
10	Data and settlement (wholesale, RERT, FCAS and SRAS)
11	DER register
12	Connecting DER
13	Network and system security with DER

Industry workshops

Industry workshops were initially held in Melbourne, Sydney and Perth to explore the SIP, TST and IDSO frameworks.

At workshops:

- For the particular ‘Function’
- For the specified ‘Activity’
- We asked participants to answer three questions
  - 1. Who is communicating with whom?
  - 2. What are they saying?
  - 3. How are they communicating (and how often)?

3. SMART GRID ARCHITECTURE MODEL DEVELOPMENT

Industry workshops

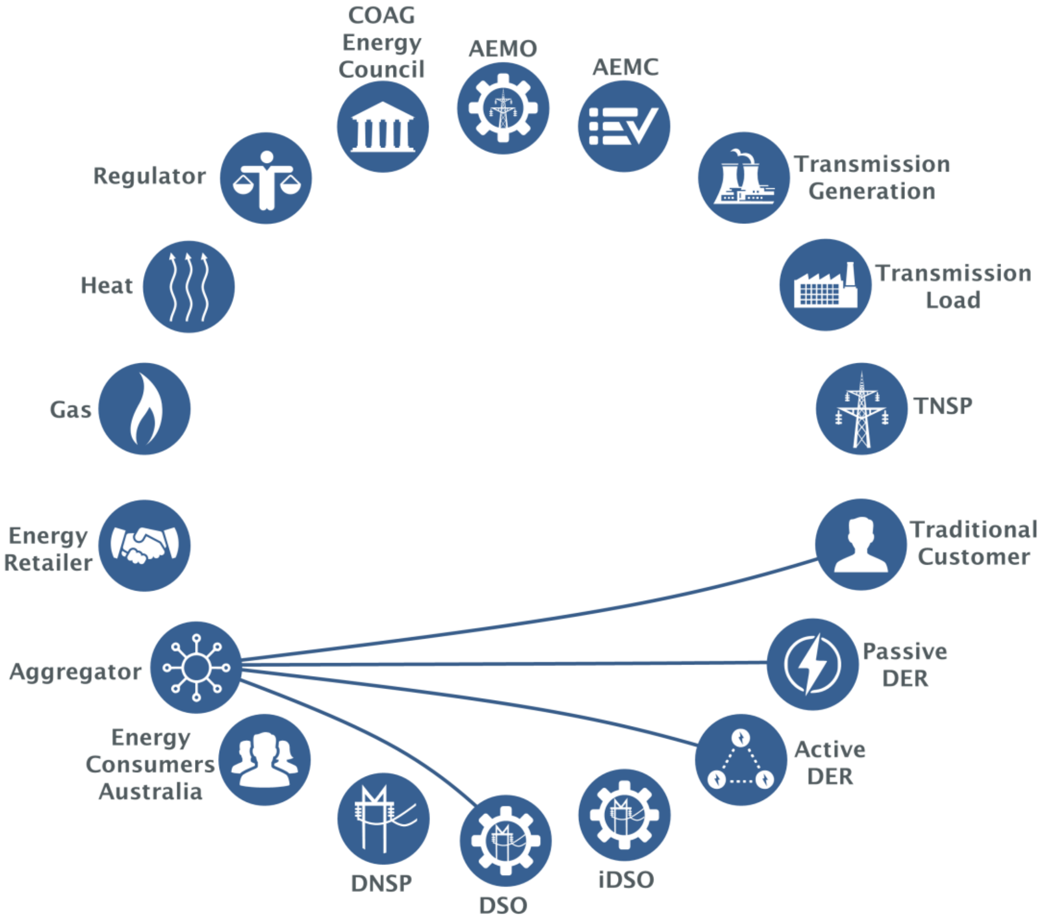
Industry workshops were initially held in Melbourne, Sydney and Perth to explore the SIP, TST and IDSO frameworks.

At workshops:

- For the particular ‘Function’
- For the specified ‘Activity’
- We asked participants to answer three questions
  - 1. Who is communicating with whom?
  - 2. What are they saying?
  - 3. How are they communicating (and how often)?

Q1. Who is communicating with whom?

Framework:	**Single Integrated Platform**
Function:	**Distribution Constraints Management**
Activity:	**DER Engagement**



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Q2. What are they saying?

Framework:	**Single Integrated Platform**
Function:	**Distribution Constraints Management**
Activity:	**DER Engagement**

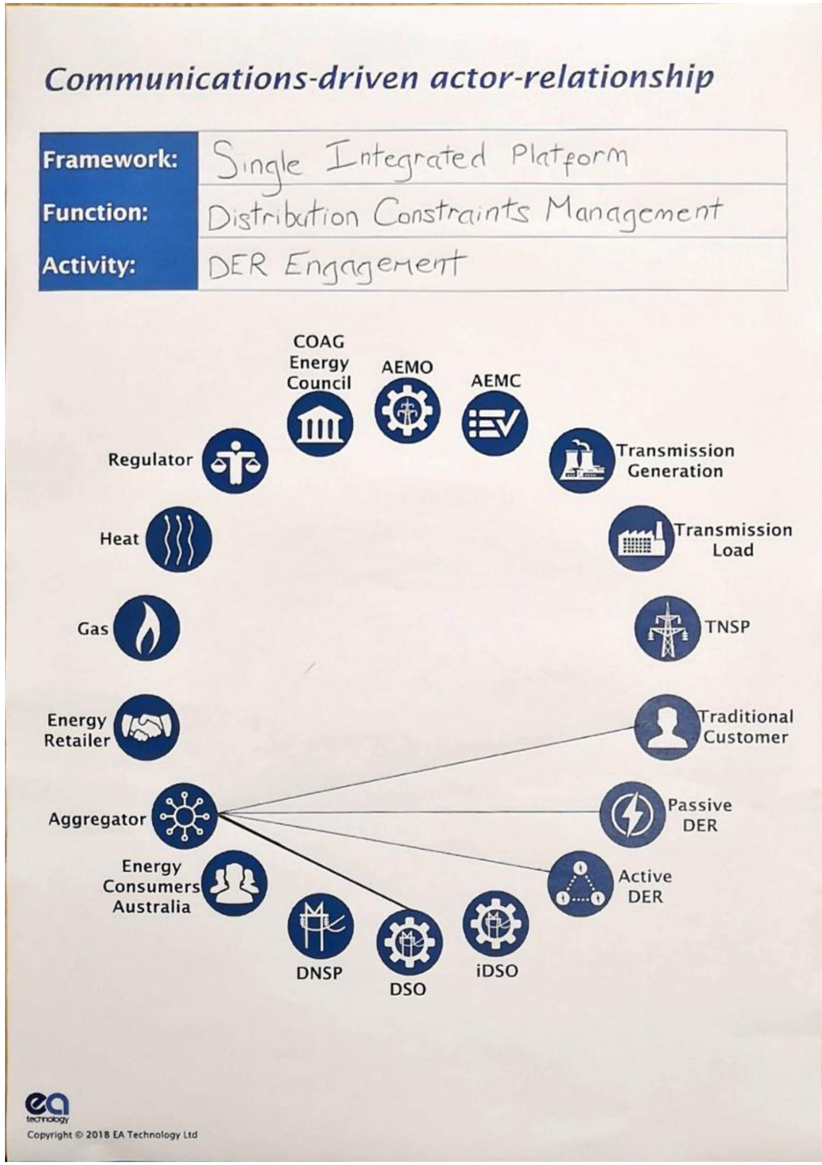
No.	From actor	To actor	Information	Type
1	DSO	Aggregator; Retailer	Sign post long-term DER requirements	
2	Aggregator; Retailer	DSO	Register interest for resource provision	
3	Aggregator; Retailer	DER	Offer conditions for sign-up	
4	DER	Aggregator; Retailer	Accept terms and conditions	
5	Aggregator; Retailer	DER	Contract DER resource	
…				

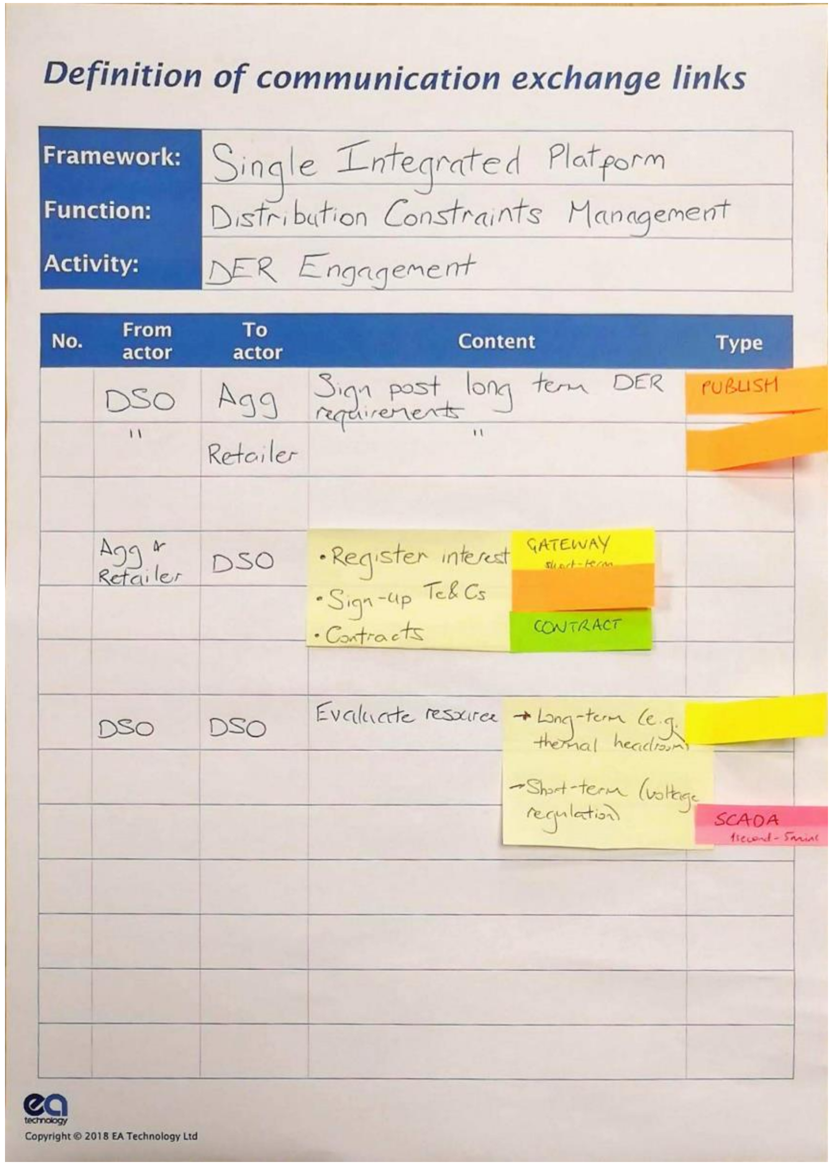
Q3. How are they communicating (and how often)?

Framework:	**Single Integrated Platform**
Function:	**Distribution Constraints Management**
Activity:	**DER Engagement**

No.	From actor	To actor	Information	Type
1	DSO	Aggregator; Retailer	Sign post long-term DER requirements	Publish
2	Aggregator; Retailer	DSO	Register interest for resource provision	Gateway
3	Aggregator; Retailer	DER	Offer conditions for sign-up	Publish
4	DER	Aggregator; Retailer	Accept terms and conditions	Gateway
5	Aggregator; Retailer	DER	Contract DER resource	Contract
…				

Application example





Definition of communication exchange links

Framework:	Single Integrated Platform
Function:	Distribution Constraints Management
Activity:	DER Engagement

No.	From actor	To actor	Content	Type
	DSO	Agg	Sign post long term DER requirements	PUBLISH
	"	Retailer	"	
	Agg & Retailer	DSO	• Register interest • Sign-up T&Cs • Contracts	GATEWAY (short-term) CONTRACT
	DSO	DSO	Evaluate resource → Long-term (e.g. thermal headroom) → Short-term (voltage regulation)	SCADA

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‘Metamodel’ creation

Workshop content was processed into ‘metamodel’ excel files to achieve consistency in the wording used and to standardise the descriptions of processes, activities and functions to a similar level of detail.

Workshop content generated:

- > 2000 data entries across all templates

Framework: Single Integrated Platform
Framework: Single Integrated Platform

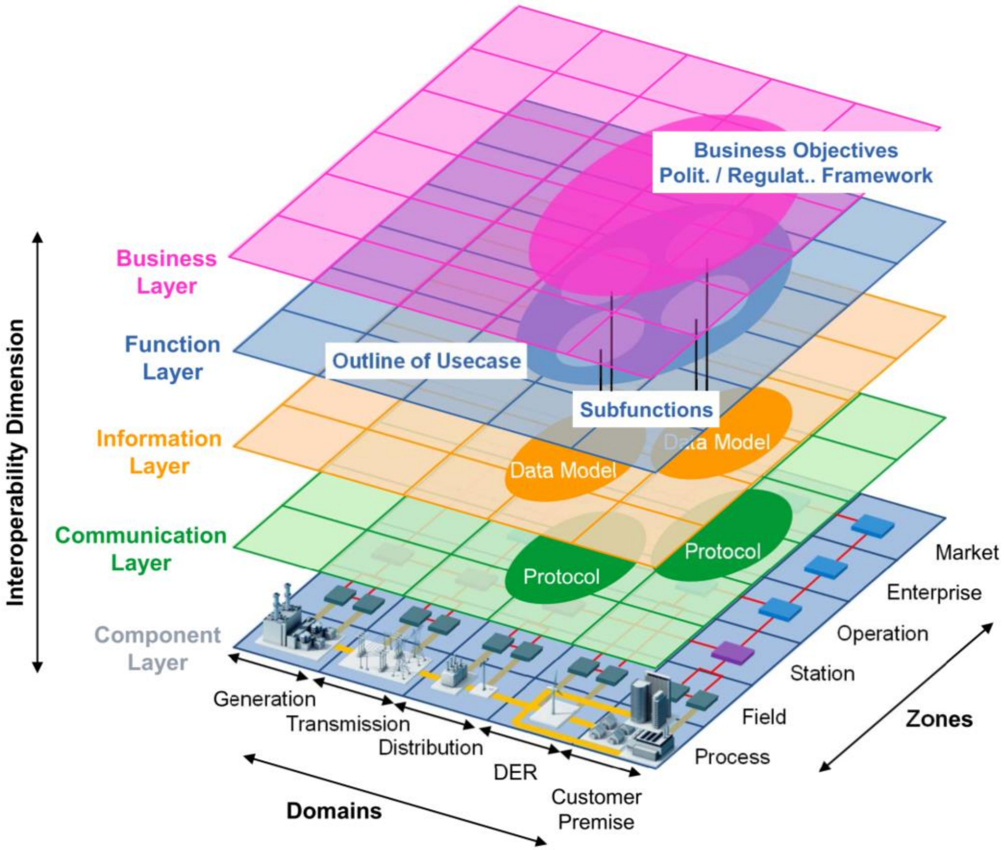
Framework: Single Integrated Platform
Function: Distribution system monitoring and planning
Activity: Gather network data

Version: 1.0
Modified by: Ray Burns
Date modified: 09/11/2018

Process no.	Process name	From actor	To actor	Step no.	Information exchange	Information name	Information description	Communication type	Notes
1	Long-term external impacts to network	Academia; CER; COAG-EC; Reg	AEMO; DSO; TNSP	1	Demographic and socio-economic factors impacting long-term network planning	Socio-economic factors	Census data, including trends in the movement of people	Contract	
		CER; COAG-EC; JB; Reg	AEMO; DSO; TNSP	2	Government policy and initiatives impacting long-term network planning	Government policy	Carbon strategy: energy efficiency standards; generation mix transition plan	Publish	
		Gas	AEMO; DSO; TNSP	3	Long-term gas usage and uptake forecasts	Gas usage	Infrastructure development plan: Capacity (volume and/or flow rate), Location	Publish	
		Academia; BOM	AEMO; DSO; TNSP	4	Long-term weather forecast data	Weather forecast	Extreme weather events: drought, heatwave, storms; Rainfall; Sunshine hours; Wind	Publish	
		Academia; EM	AEMO; DSO; TNSP	5	Long-term trends in technology development and deployment	Technology trends	Technology costs; EV uptake; Battery uptake; Upcoming developments in technology	Publish	
2	Long-term D-network forecast	DSO	DSO	1	Gather historic data from DSO monitoring equipment	Historic D-network data	Active power; Reactive power; Voltage; Current; Power quality; Time; Location; Other	Gateway	
		A-DER; P-DER; TC	DSO	2	D-network connection requests	Connection request	Connection type; Capability; Capacity; Location	Publish	
		MC	DSO	3	Historic metering data of D-network end-customers	Metering data	Active power; Reactive power; Voltage; Current; Power quality; Time; Location (NMI); Other	Gateway	
		A-DER; Agg; ER; P-DER	DSO	4	Technical characteristics of D-network end-customer assets	End-customer characteristics	Load assets; Generation assets; Storage; Power electronics, including inverter capability	Publish	
		A-DER; Agg; ER; P-DER	DSO	5	Forecast long-term D-network end-customer load and generation profiles within entitlement	End-customer data profiles	Connection agreement and regulatory entitlement to import / export; Active power; Reactive power; Voltage; Current; Power quality; Time; Location (NMI); Operational impacts; Other	Gateway	
		DSO	DSO	6	Develop updated internal forecasting tools incorporating DER impacts on the D-network	Forecasting tools	Hardware and/or software solution	Publish	

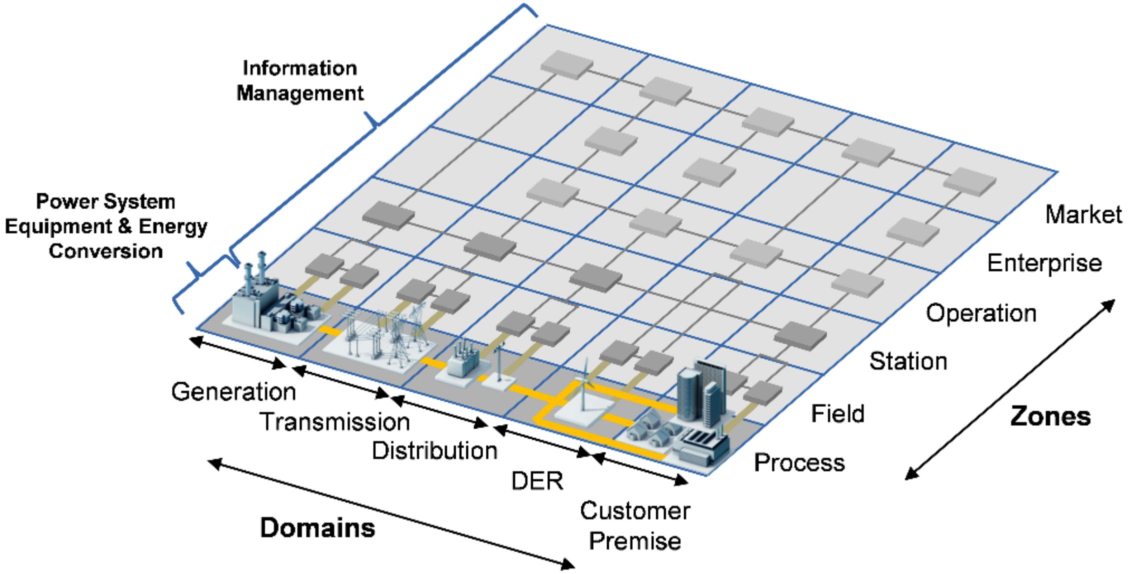
EA Technology | Change Log | Actors Key | Comms Key | Function | Activity I | Activity II

Smart Grid Architecture Model (SGAM)



- Interoperability layers
  - **Business** layer: provides a business view on the information exchange related to Smart Grids. Business objectives, capabilities and processes can be mapped on this layer.
  - **Function** layer: describes functions and services including their relationships from an architectural viewpoint.
  - **Information** layer: describes information objects being exchanged and the underlying data models.
  - **Communication** layer: describes protocols and mechanisms for the exchange of information between components.
  - **Component** layer: physical distribution of all participating components including power system and ICT equipment.
- Domains
  - Electric energy conversion chain
- Zones
  - Hierarchy of power system management

Smart grid plane



Domains

- Generation
- Transmission
- Distribution
- DER
- Customer premises
- Non-electrical vectors

Zones

- Process
- Field
- Station
- Operation
- Enterprise
- Market

SGAM development methodology

SGAM development process

Basis for bespoke EA Technology SGAM execution for OpEN-PRJ

I. System analysis phase

Use case analysis → Function layer → Business layer

- Aims to define the system and its functional requirements
- Focus is on the required functional specification of a model rather than on technical or physical solutions
- Describes business actors, their objectives and their interactions

▶ Complete

Basis for further work that may be added at a later date once there is greater confidence in a selected framework

II. System architecture phase

Component layer → Information layer → Communication layer

- Aims to map the functional requirements of the system into a high-level architecture
- Describes the main physical subsystems and their interactions without detailing their inner composition.

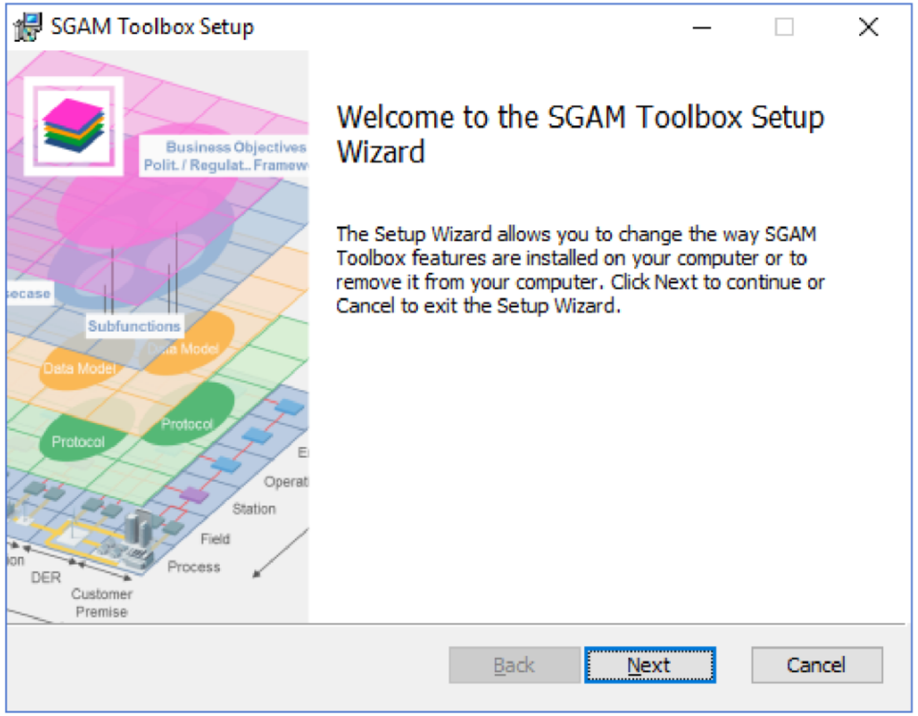
▶ May be developed following framework selection

The software tool we used

Enterprise Architect

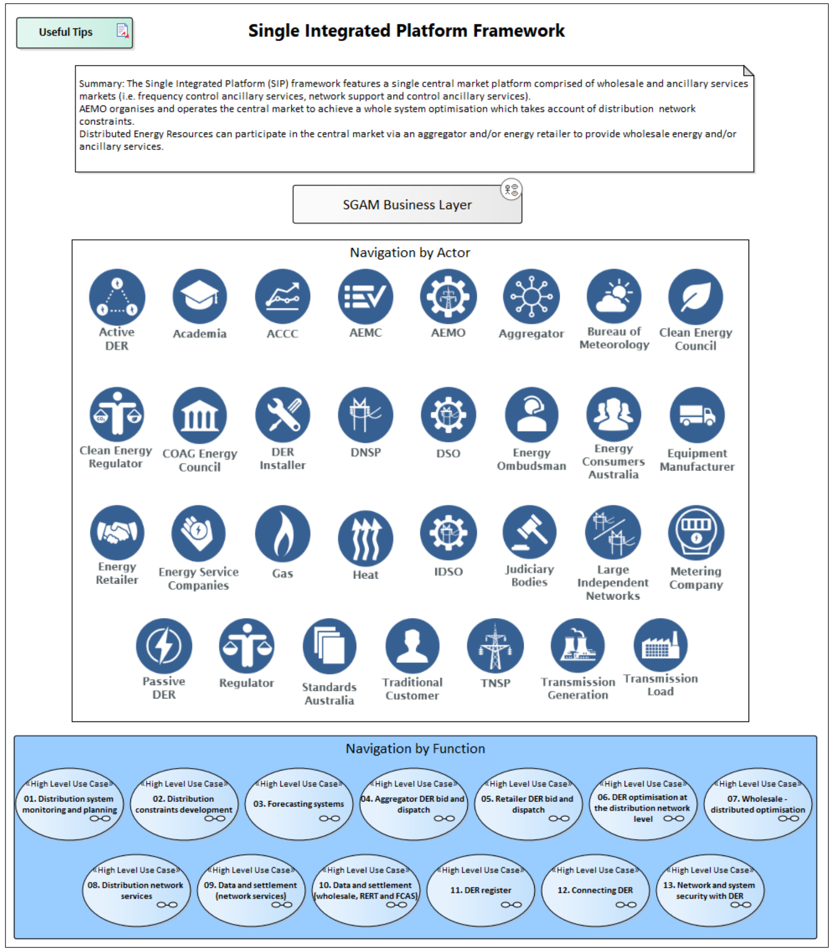
- “Enterprise Architect” from Sparx Systems
- Originally Desktop Edition Standard License
- Moving to Corporate Edition
- http://sparxsystems.com/

SGAM Toolbox



- “SGAM-Toolbox” from the ‘Centre for Secure Energy Informatics’ at the Salzburg University of Applied Sciences
- https://sgam-toolbox.org/download

SGAM walkthrough



Model Demo

The SGAM is developed through 'use case analysis' where each of the DSO framework options is selected and analysed in detail. We will explore the following use case:

- Framework: Single Integrated Platform
- Function: 4. Aggregator DER bid and dispatch
- Activity: 3. Aggregator market engagement
- Process: 1. Market registration

Navigation of:

- The landing page
- The business layer diagram
- The actor view diagram
- The HLUC (function) diagram
- The PUC (activity) diagram
- The sequence diagram
- The activity diagram

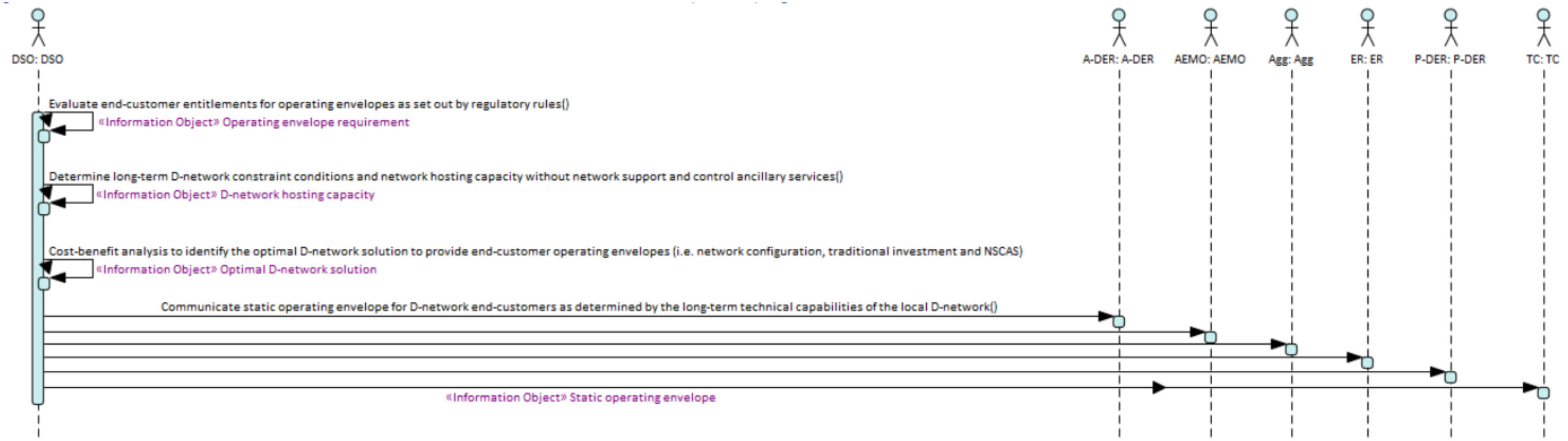
Use case comparison - SIP

The SGAM is developed through 'use case analysis' where each of the DSO framework options is selected and analysed in detail. We will explore the following use case:

– Function: 6. DER optimisation at the distribution network level

– Activity: 1. Optimise operating envelopes of distribution network end-customers

– Process: 2. Communicate operating envelopes to D-network end-customers (long-term)



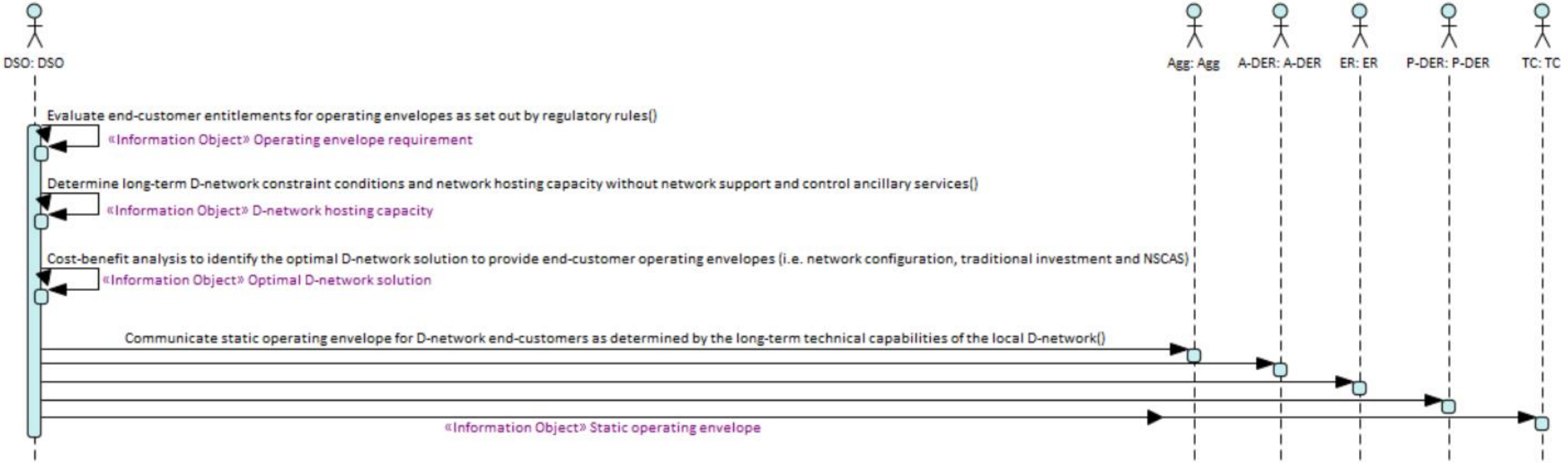
Use case comparison - TST

The use case:

– Function: 6. DER optimisation at the distribution network level

– Activity: 1. Optimise operating envelopes of distribution network end-customers

– Process: 2. Communicate operating envelopes to D-network end-customers (long-term)



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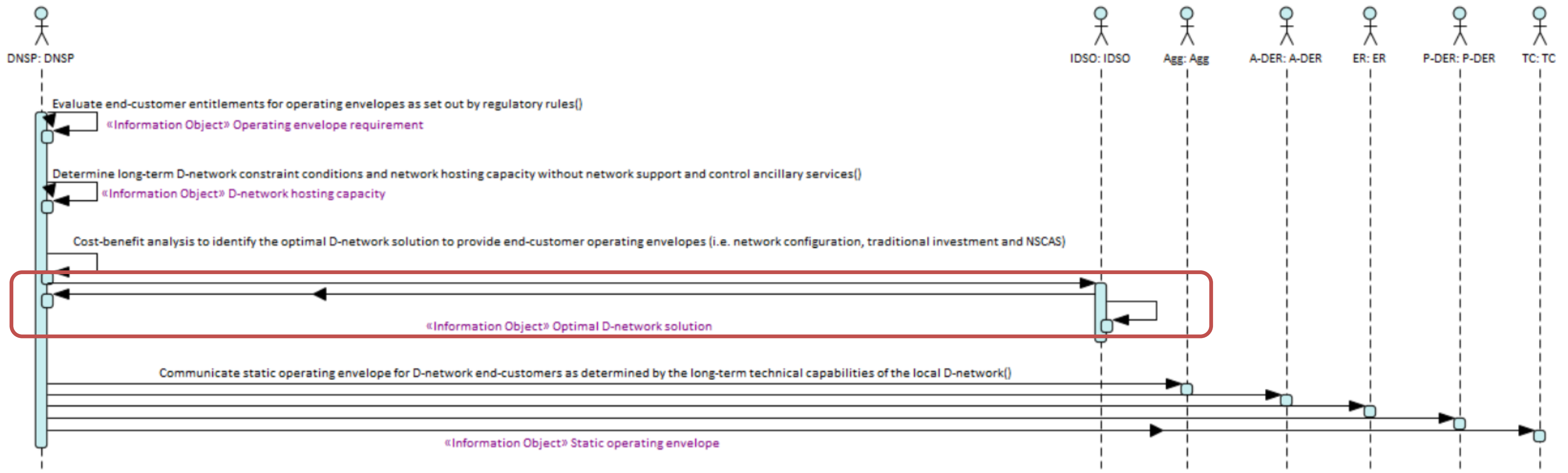
Use case comparison - IDSO

The use case:

– Function: 6. DER optimisation at the distribution network level

– Activity: 1. Optimise operating envelopes of distribution network end-customers

– Process: 2. Communicate operating envelopes to D-network end-customers (long-term)



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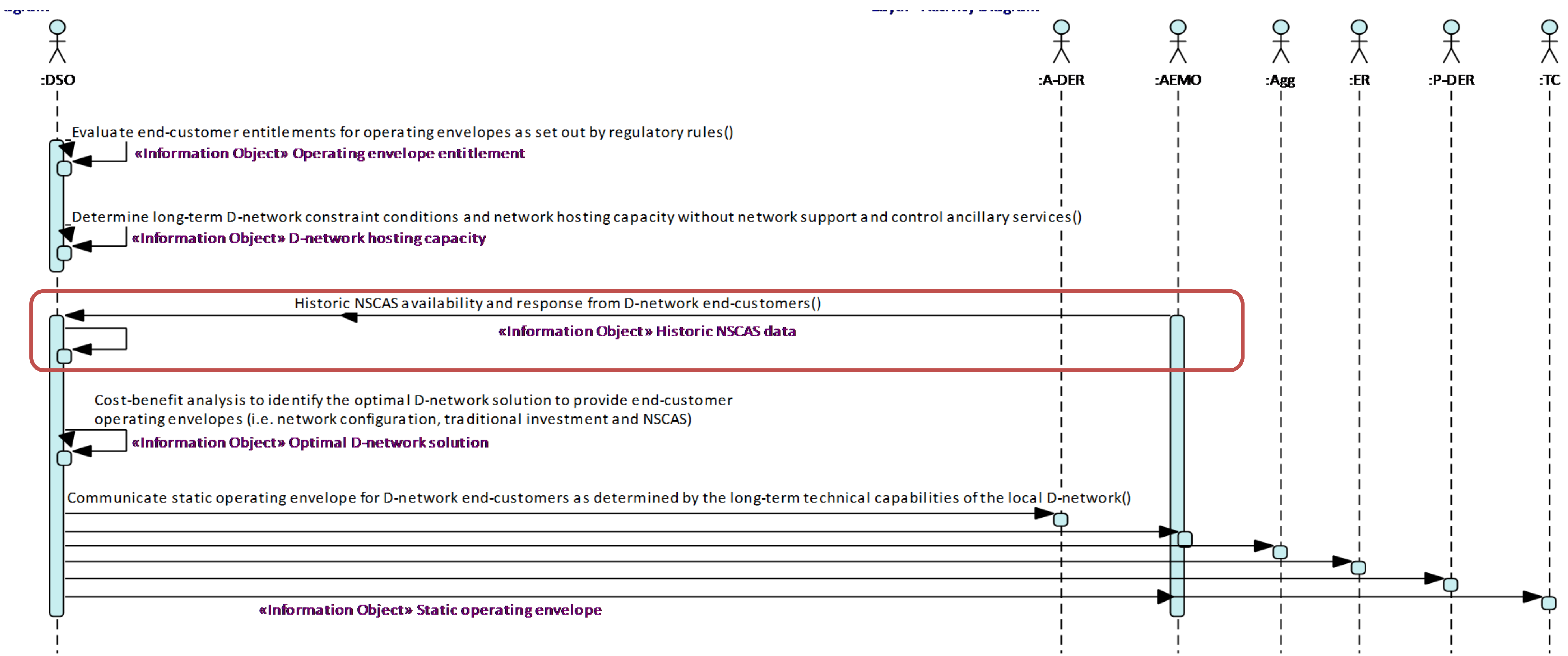
Use case comparison - Hybrid

The use case:

– Function: 6. DER optimisation at the distribution network level

– Activity: 1. Optimise operating envelopes of distribution network end-customers

– Process: 2. Communicate operating envelopes to D-network end-customers (long-term)



4. SGAM ANALYSIS

Level of change

We can assess the level of change needed to establish each DSO framework by evaluating the **relative complexity** of each.

This is determined by assessing the 'linkage index' and 'replication index' of each step within the SGAMs.

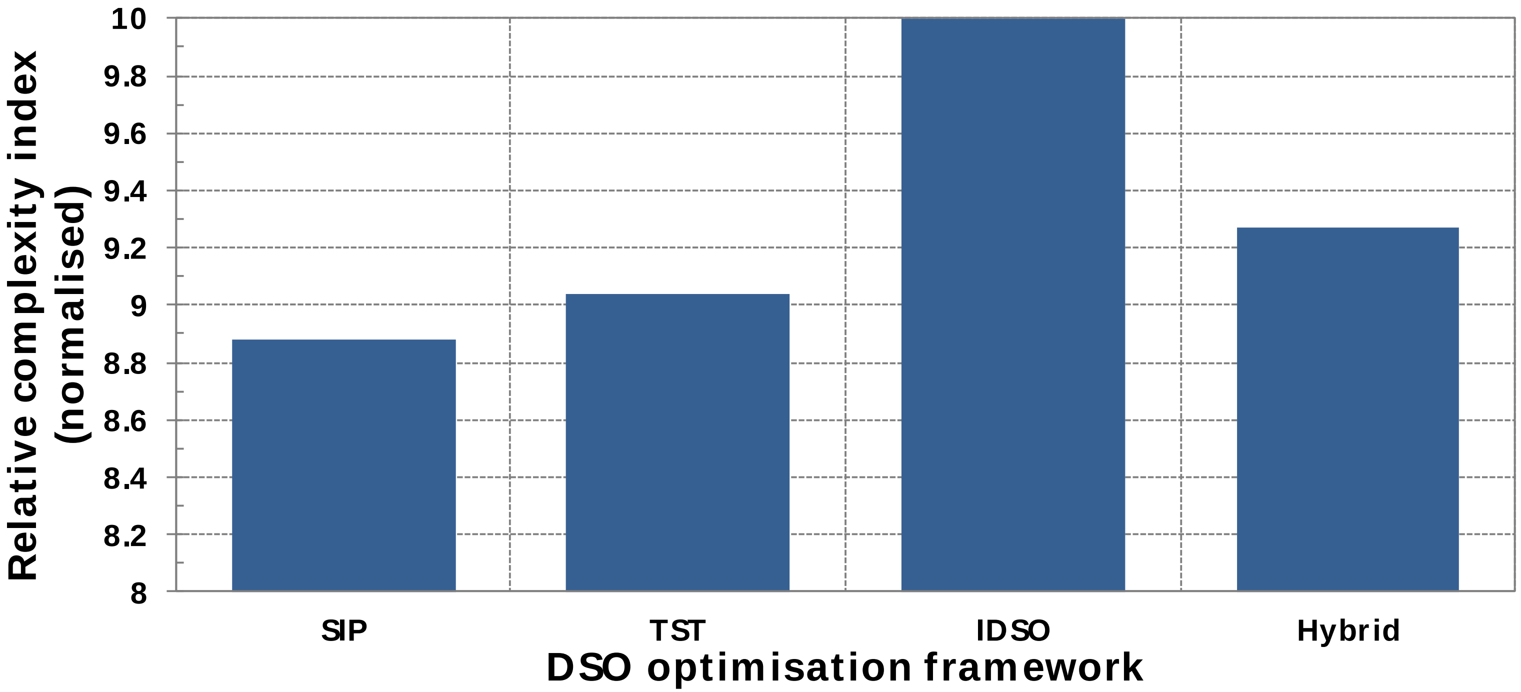
Linkage index

- Measures the **nature of the communications** between actors in each model step
- Real-time exchange of data is inherently more complex than publishing a statement
- Publish (1); Contract (2); Gateway (3); SCADA (5)

Replication index

- Measures the **volume of communication** between actors in each model step
- Communicating data to millions of customers is more complex that conversing with a single entity
- From single actor entities like AEMO (1) to traditional customers (7)

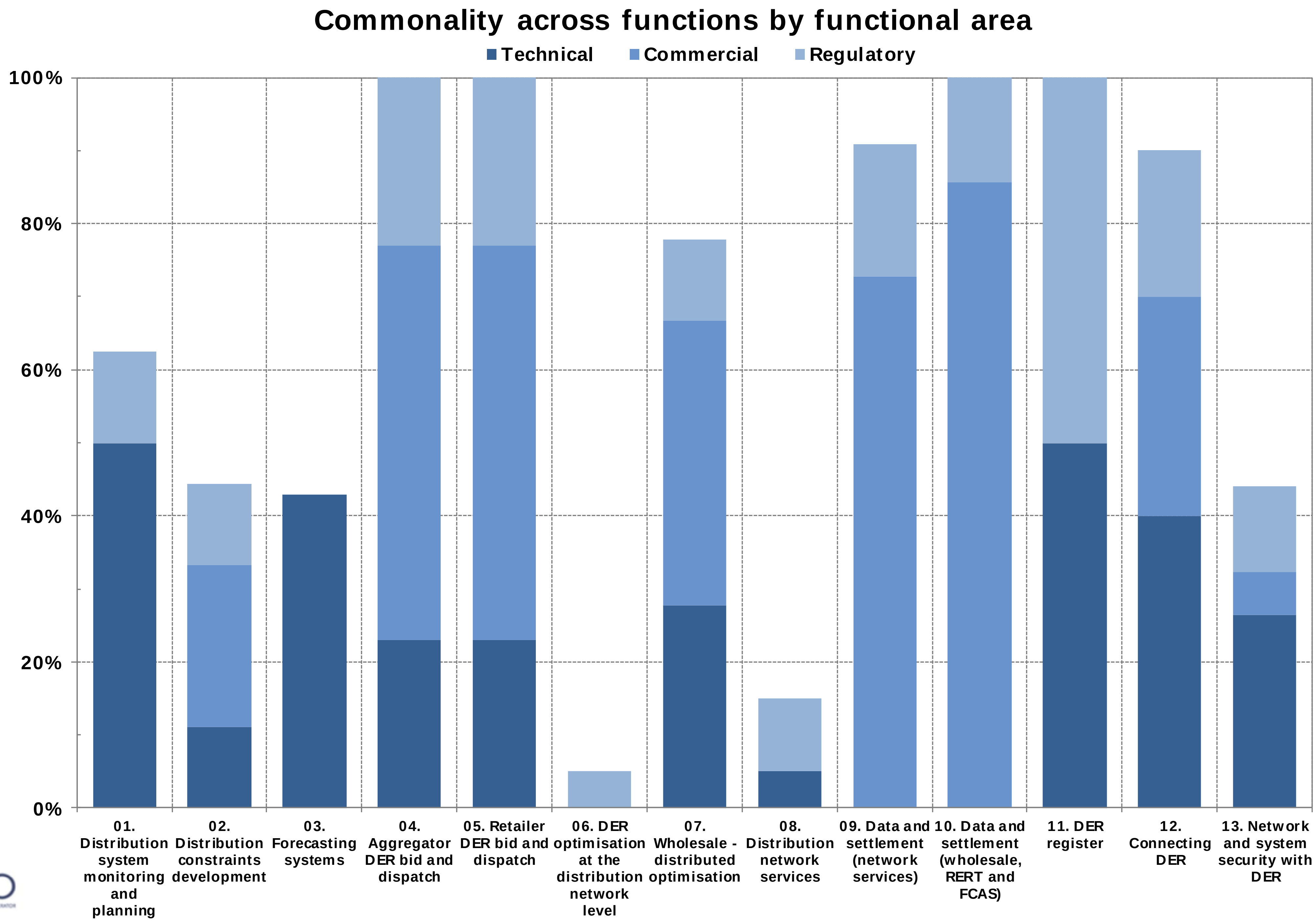
Framework complexity



Relatively stable across frameworks

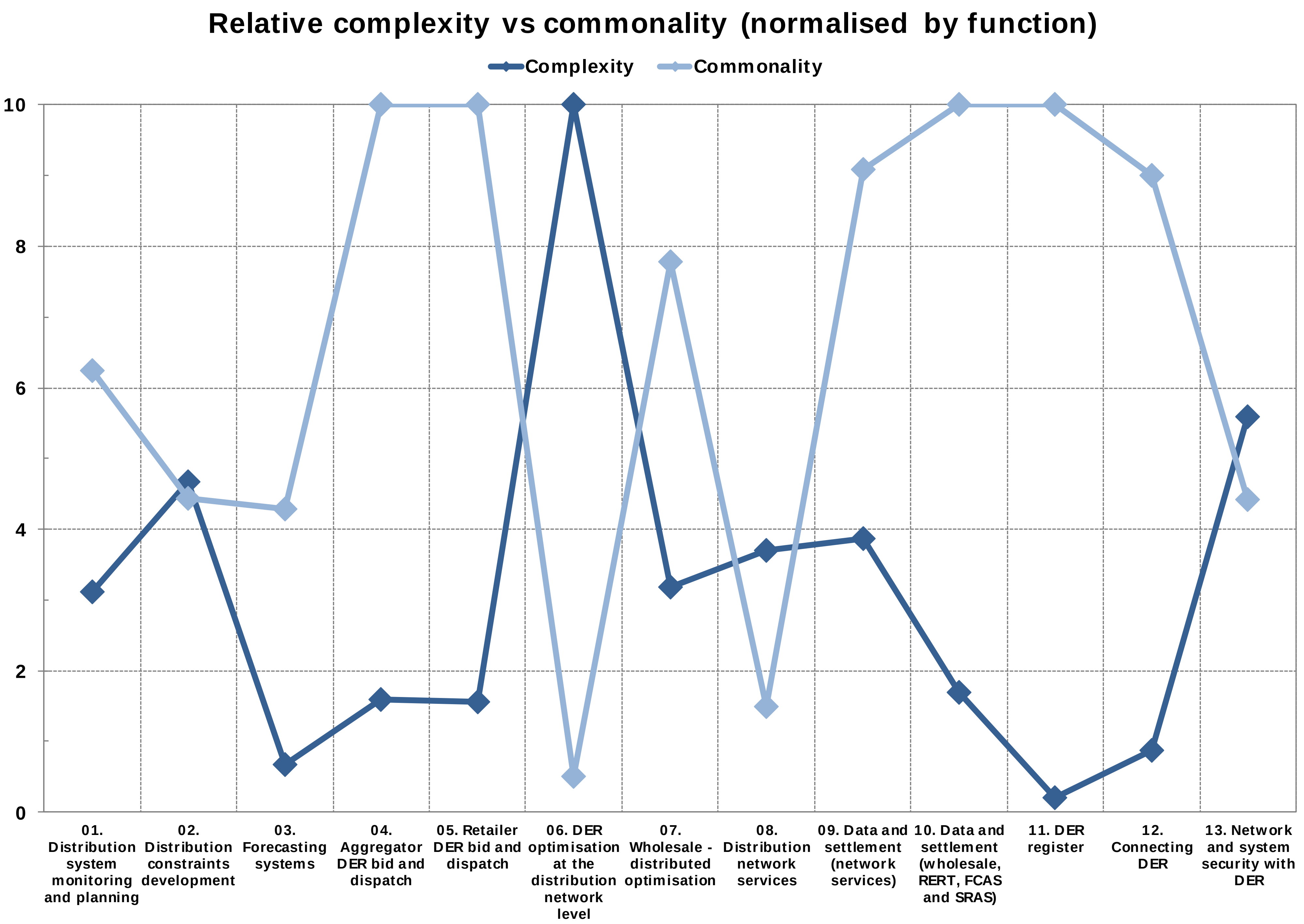
1. SIP – Lowest complexity as closest to current practice
2. TST – Raised complexity due to requirement for new market platform
3. Hybrid - Raised complexity due to requirement for new market platform and increased AEMO-DSO communication
4. IDSO – Highest complexity due to requirement for new market platform and new regulated entity

High complexity should not exclude a framework as it may correspond with greater value to customers.



AEMO

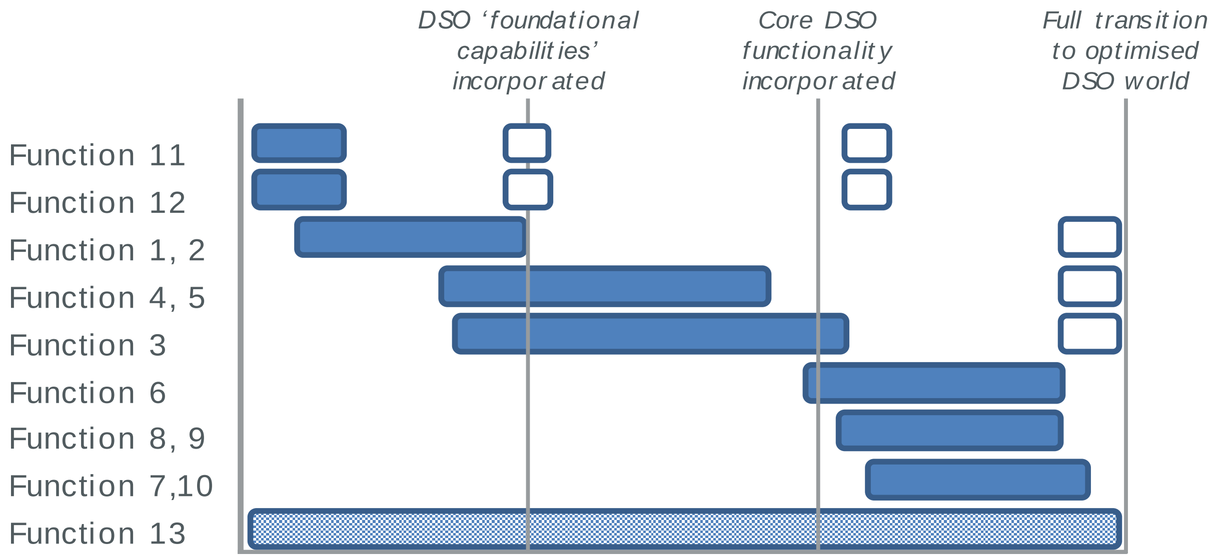
Energy Networks Australia


Relative complexity vs commonality (normalised by function)
Complexity
Commonality
10
8
6
4
2
0
01. Distribution system monitoring and planning
02. Distribution constraints development
03. Forecasting systems
04. Aggregator DER bid and dispatch
05. Retailer DER bid and dispatch
06. DER optimisation at the distribution network level
07. Wholesale - distributed optimisation
08. Distribution network services
09. Data and settlement (network services)
10. Data and settlement (wholesale, RERT, FCAS and SRAS)
11. DER register
12. Connecting DER
13. Network and system security with DER

Conceptual Pathways forward

- Foundational capabilities provide a starting point
- Least regret recommendations give insight into low risk areas to pursue and explore

But, in order to embark on the full system transition it will be necessary to make key choices as soon as possible to be prepared for the future. i.e. preferred framework, the pathway forward...



Indicative Implementation Pathway

Key

- New capabilities decided and implemented
- Capabilities revised and updated
- A workstream responsive to related developments elsewhere

1 Distribution system monitoring and planning
2 Distribution constraints development
3 Forecasting systems
4 Aggregator DER bid and dispatch
5 Retailer DER bid and dispatch
6 DER optimisation at the distribution network level
7 Wholesale - distributed optimisation
8 Distribution network services
9 Data and settlement (network services)
10 Data and settlement (wholesale, RERT, FCAS and SRAS)
11 DER register
12 Connecting DER
13 Network and system security with DER

Pathway indicators

To understand and track progress it is important to be aware of:

The start point

- The current uptake level of DER
- The network and asset characteristics and capabilities
- Trialled solutions

The end point

- The forecast point prior to which intervention will be required in order to maintain reliable and safe supply

Factors and influences

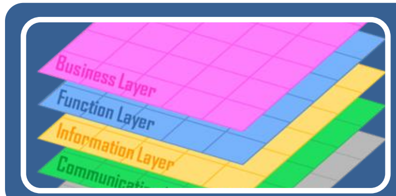
- National / global economic circumstance
- DER technology costs and availability
- Government policy and incentives

Although key decisions must be made to shape the way forward, the network transformation is a continuing and interactive process where each stakeholder's journey will be different and the direction of travel may change over time.

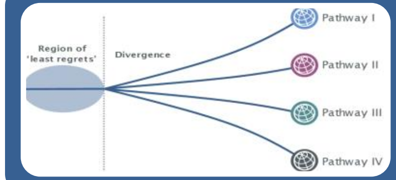
Stakeholders must be attuned to the latest industry data and milestones to understand how the transition is progressing and determine their path forward.

Summary

We have:



Developed and represented the four frameworks in Smart Grid Architecture Models



Explored commonality across the frameworks to identify actions to pursue in the near-term

Identified that to unlock full DER potential it is advantageous to select an end-state to transition toward

Engaged with industry and now encourage stakeholders to explore and interact with the SGAMs of the frameworks

Session 4

Cost-benefit analysis frameworks for DER integration

Cost-benefit analysis frameworks for DER integration

Open Energy Networks Workshop

Paul Graham | Chief Economist Energy

March 2019

Outline

- Frameworks, recommendation
- BAU / counterfactual design
- Findings from existing studies
- Implications for timing
- Next steps

Motivation / research questions

- DER integration will require new costs – are the benefits worth it at a whole of system level?
- If there are positive net benefits, how soon do we need to establish the system?
- How do we choose between different systems/models?
- New information: new CBA studies; updated DER projections

Frameworks: US approach

New York	California
Bulk	Avoided T&D
• Avoided Generation Capacity Costs, including Reserve Margin	• Sub-Transmission/Substation/Feeder
	• Distribution Voltage/Power Quality
• Avoided Energy	• Distribution Reliability/Resiliency
• Avoided Transmission Capacity	• Transmission
Infrastructure and O&M	Avoided Generation Capacity
• Avoided Transmission Losses	• System and Local Resource Adequacy
• Avoided Ancillary Services	• Flexible Resource Adequacy
Distribution System	Avoided Energy
• Avoiding Distribution Capacity Infrastructure	Avoided Greenhouse Gas Emissions
• Avoided O&M Costs	Avoided Renewable Portfolio Standard[1]
• Avoided Distribution Losses	Avoided Ancillary Services
Reliability/Resiliency	• Renewable Integration Costs
• Net Avoided Restoration Costs	Societal Avoided Costs
• Net Avoided Outage Costs	• Public Safety Costs
External	
• Net Avoided Greenhouse Gas Emissions	
• Net Avoided Criteria Air Pollutants	
• Avoided Water Impacts	
• Avoided Land Impacts	
• Net Non-Energy Utility Benefits	

Frameworks: applied analysis

Study	Benefits included	Costs included
Electricity Networks Transformation Roadmap (CSIRO)	Avoided generation expenditure Avoided distribution expenditure Avoided transmission expenditure Avoided balancing solution capacity under high VRE	Not applicable
UK Open Networks / (Baringa Partners)	Avoided transmission investment Avoided distribution investment Reduced balancing costs Avoided generation investment (all modified by certainty of response, degree of control and participation)	Technology costs Resource costs (skills, time volume) Business transition costs Interface costs between actors
SAPN LV management business case	Avoided generation expenditure	LV network monitoring and signalling of hosting capacity constraints
Integrated System Plan (High DER)	Avoided generation expenditure Avoided transmission expenditure	Not applicable

Recommended approach to DER integration CBA

- DER integration creates impacts all along the supply chain – we need to capture them without making the analysis intractably large.

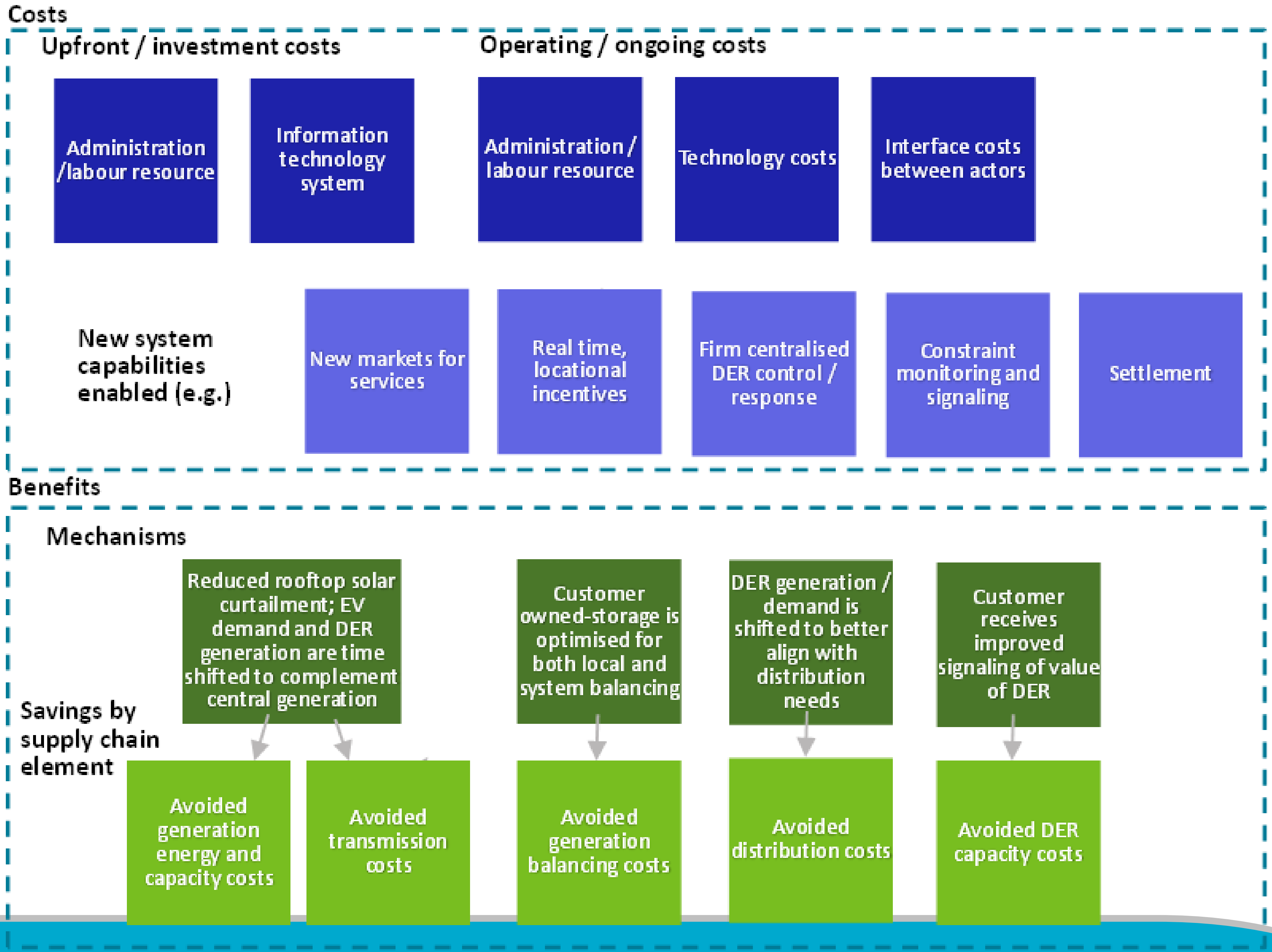
- Exclude:
  - Externalities on both the cost and benefit side associated with environmental impacts (e.g. emissions, land and water)
  - Safety-related costs or benefits
  - Outage and restoration-related costs or benefits

- Approach to DER equipment costs depends on BAU (e.g. degree of VPP readiness) and quality of incentives

Recommended approach to DER integration CBA

Transmission (ISP findings)

- The ISP 2018 found that state interconnectors were still required regardless of level of DER – to connect diverse wind
- However, the level of DER impacts the level of interstate connections required for large scale solar
- Not likely to be a large source of avoided costs but still warrants inclusion


Costs
Upfront / investment costs
Operating / ongoing costs
Administration /labour resource
Information technology system
Administration / labour resource
Technology costs
Interface costs between actors
New system capabilities enabled (e.g.)
New markets for services
Real time, locational incentives
Firm centralised DER control / response
Constraint monitoring and signaling
Settlement
Benefits
Mechanisms
Reduced rooftop solar curtailment; EV demand and DER generation are time shifted to complement central generation
Customer owned-storage is optimised for both local and system balancing
DER generation / demand is shifted to better align with distribution needs
Customer receives improved signaling of value of DER
Savings by supply chain element
Avoided generation energy and capacity costs
Avoided transmission costs
Avoided generation balancing costs
Avoided distribution costs
Avoided DER capacity costs

Questions for group

- Are there elements that the proposed CBA framework should emphasise more?
- Are there elements that the proposed framework should de-emphasise?

BAU / DER non-integration definition

- Meaning: no centralised attempt to coordinate DER
- Aggregators exist but those activities are impacted by the uncontrolled activities of other DER owners
- Customers, Retailors, Networks and AEMO will respond in other ways to DER uptake impacts

Updated DER projections, ESOO 2018

		Residential rooftop solar	Commercial rooftop solar	Residential battery storage	Commercial battery storage	Electric vehicles	Electric vehicle p.a. electricity demand
		MW	MW	MWh	MWh	No.	GWh
2020	Slow	7842	2094	647	27	3,966	31
	Moderate	9795	3257	1100	69	10,688	55
	Fast	10183	3840	1161	82	18,342	84
2030	Slow	9981	4009	1622	72	456,318	1506
	Moderate	13869	6104	3362	243	1,716,214	5761
	Fast	15199	7861	5424	456	3,242,170	12056
2040	Slow	12661	5651	3127	193	4,973,668	15745
	Moderate	21300	9053	8794	868	7,164,739	24225
	Fast	28344	13397	16444	1833	10,019,327	39218
2050	Slow	19581	9301	5586	414	9,199,969	29318
	Moderate	26009	12978	17877	2138	11,032,809	37947
	Fast	38426	20801	29778	4083	15,015,551	59953

Impact of DER adoption

AEMO projections of minimum demand indicate risk of negative state demand (90% POE)

- South Australia
  - 2023 under the Slow scenario
  - Neutral scenario in 2024
  - 2026 for the Fast scenario
- Queensland
  - 2031 under Slow scenario
- Victoria
  - 2034 under Slow scenario

Impact of DER adoption

AEMO projections of minimum demand indicate risk of negative state demand (90% POE)

- South Australia
  - 2023 under the Slow scenario
  - Neutral scenario in 2024
  - 2026 for the Fast scenario
- Queensland
  - 2031 under Slow scenario
- Victoria
  - 2034 under Slow scenario

How do you manage a system for outages where all electricity is supplied by uncontrolled plant?

Managing negative demand without DER central coordination

Some options on negative demand day in SA:

- Select ancillary services from a plant that is spinning but not supplying energy within the state
- Simultaneously importing energy into South Australia such as would be possible under the proposed second NSW-SA interconnector
- Purchasing some conventional demand management

Impact of DER adoption

At around 40% solar penetration at the distribution level, limits in the capacity of the network will result in

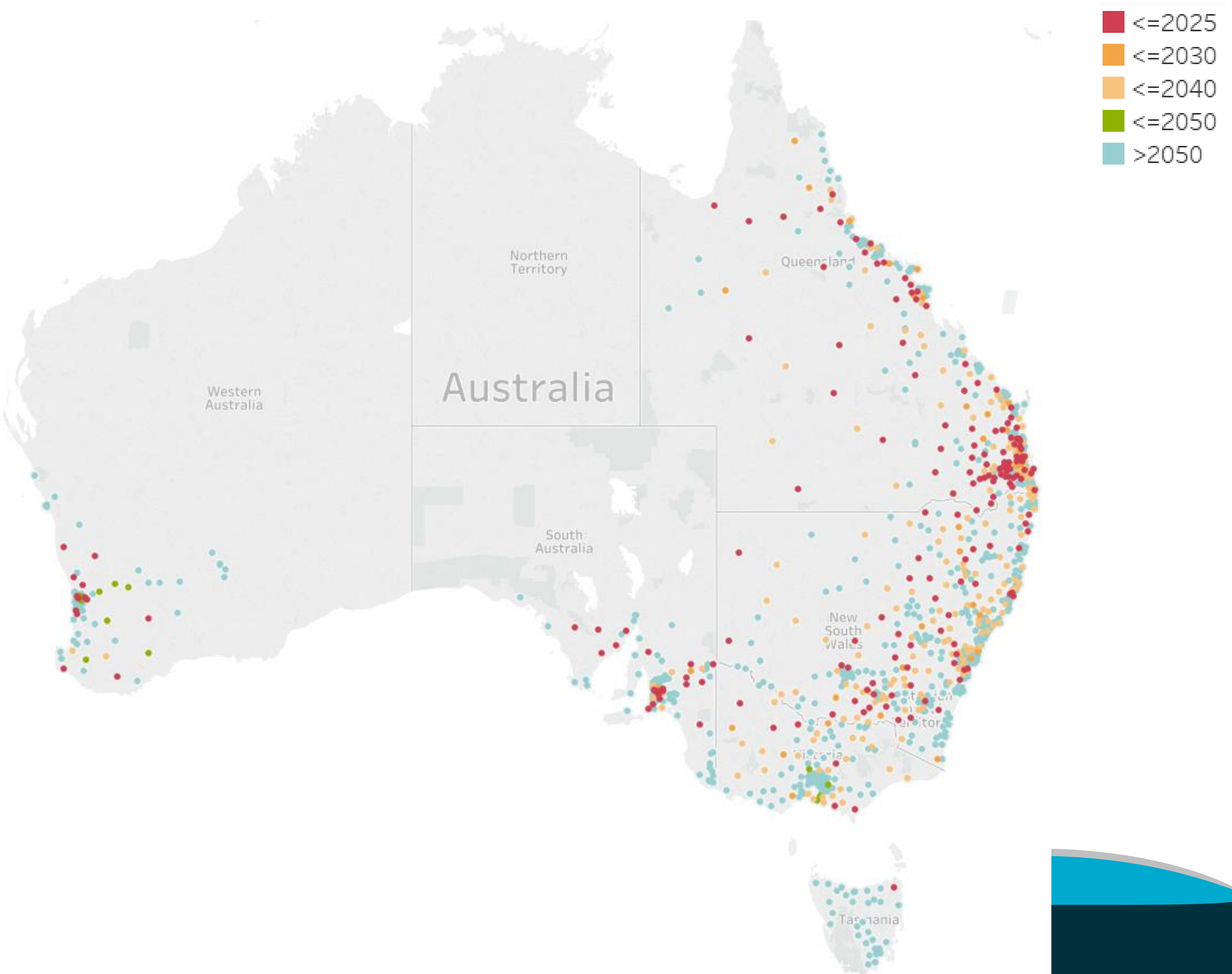
- Widespread inverter tripping (voltage exceedance)
  - SAPN find this result even taking into account new inverter standards

- Potential for outages (thermal exceedance)
  - More a risk from coincident battery operation

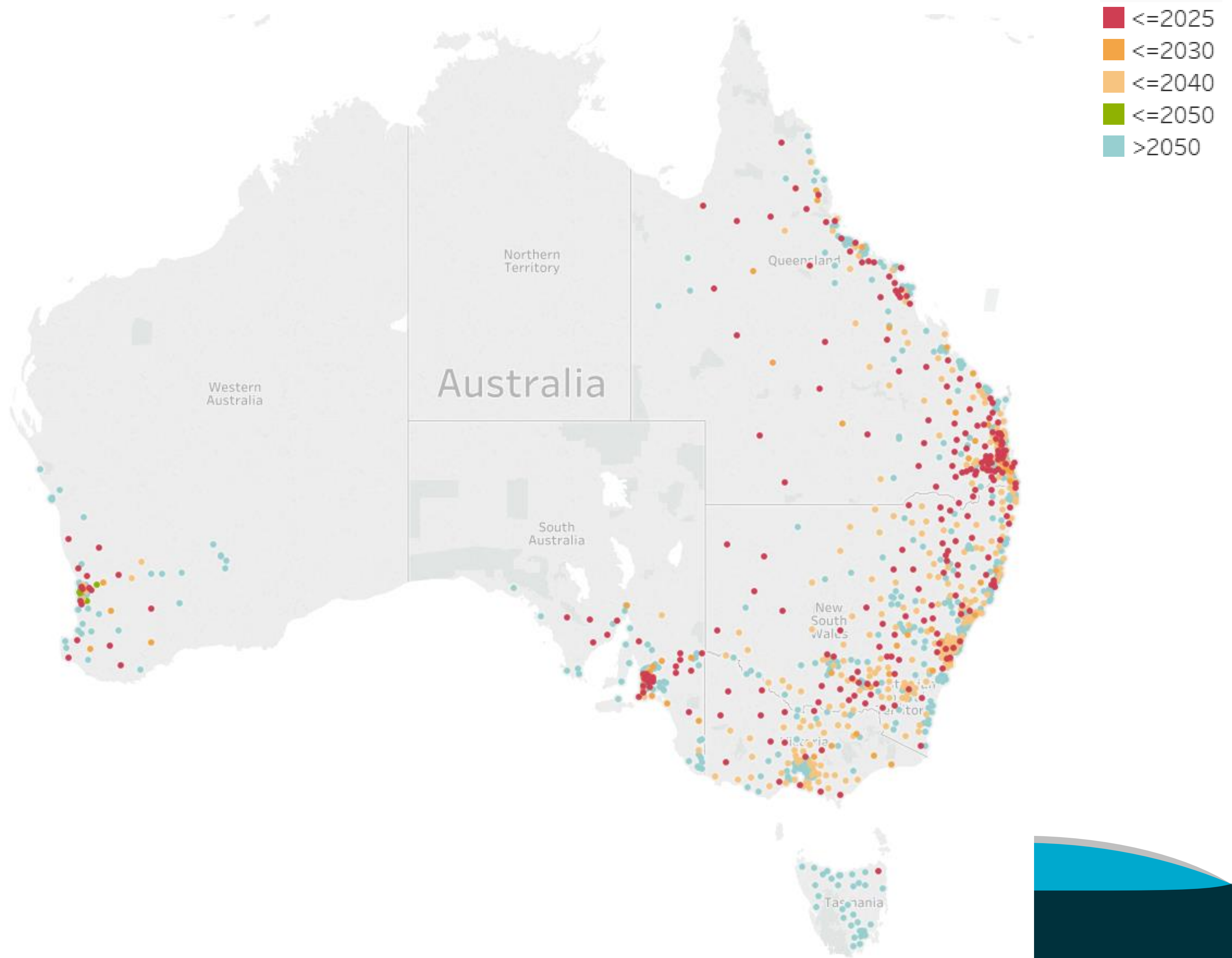
- CSIRO / ENTR also found that a zone substation will experience negative demand at this penetration

CSIRO

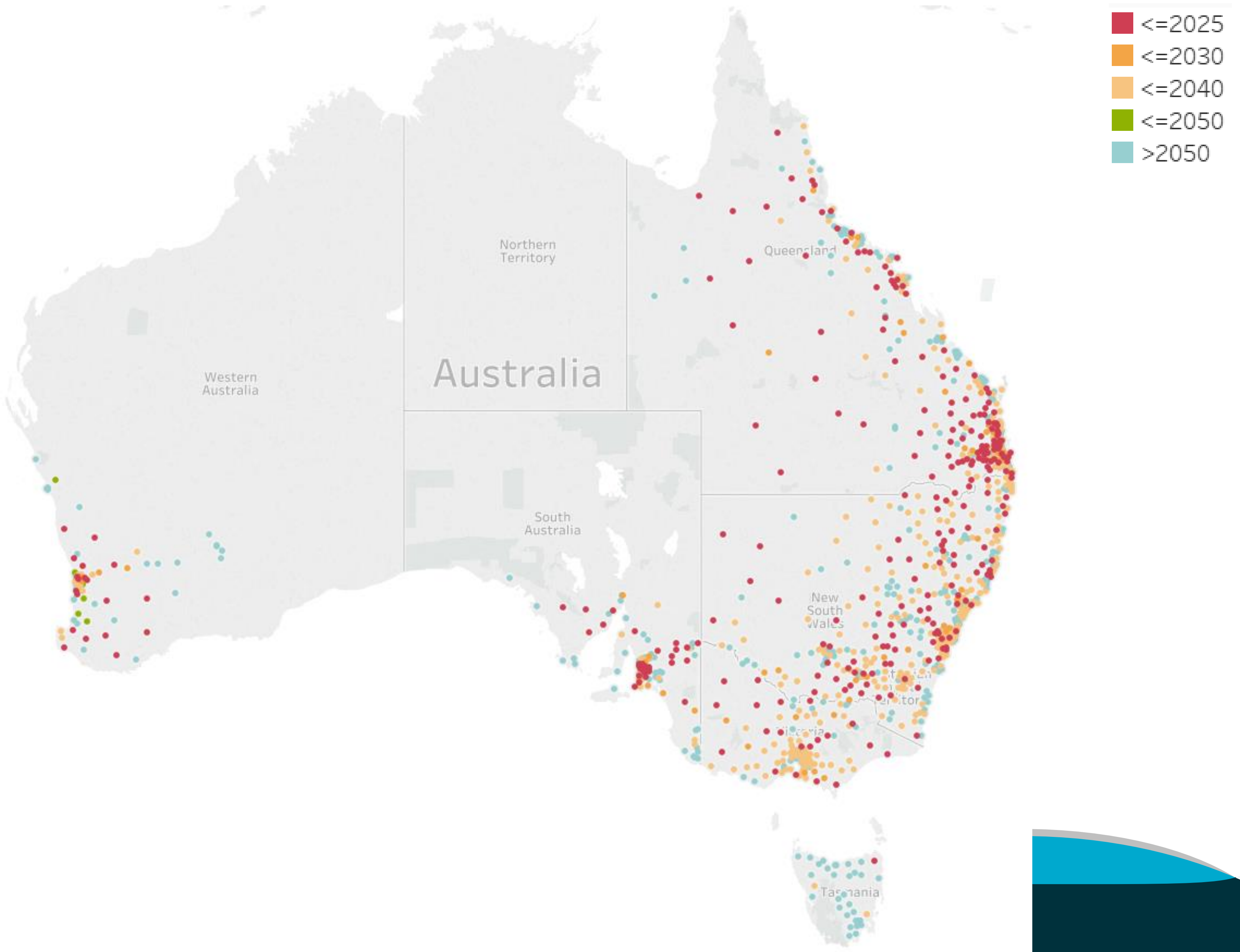
Period in which zone substation experiences negative demand: ESOO Slow



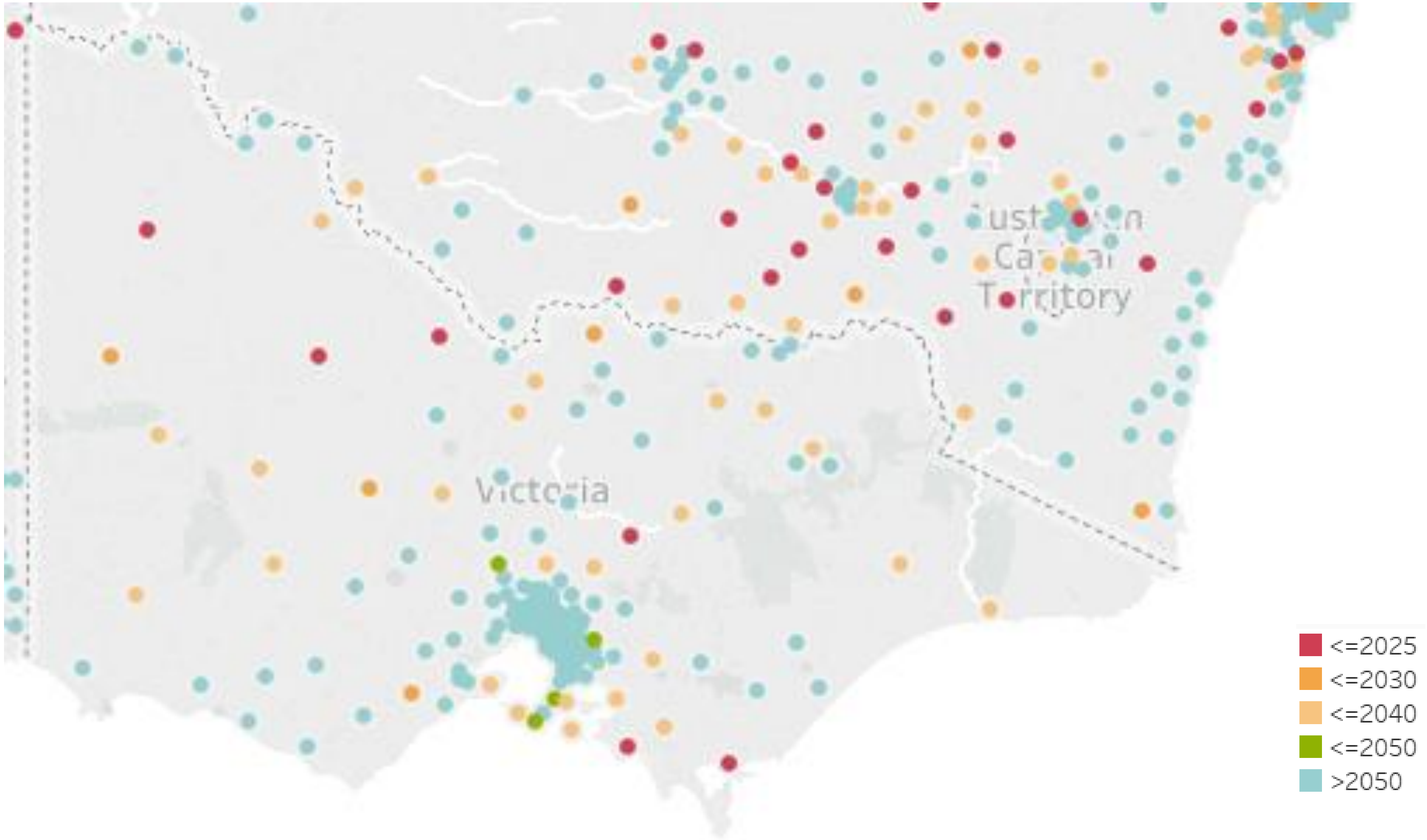
Period in which zone substation experiences negative demand: ESOO neutral



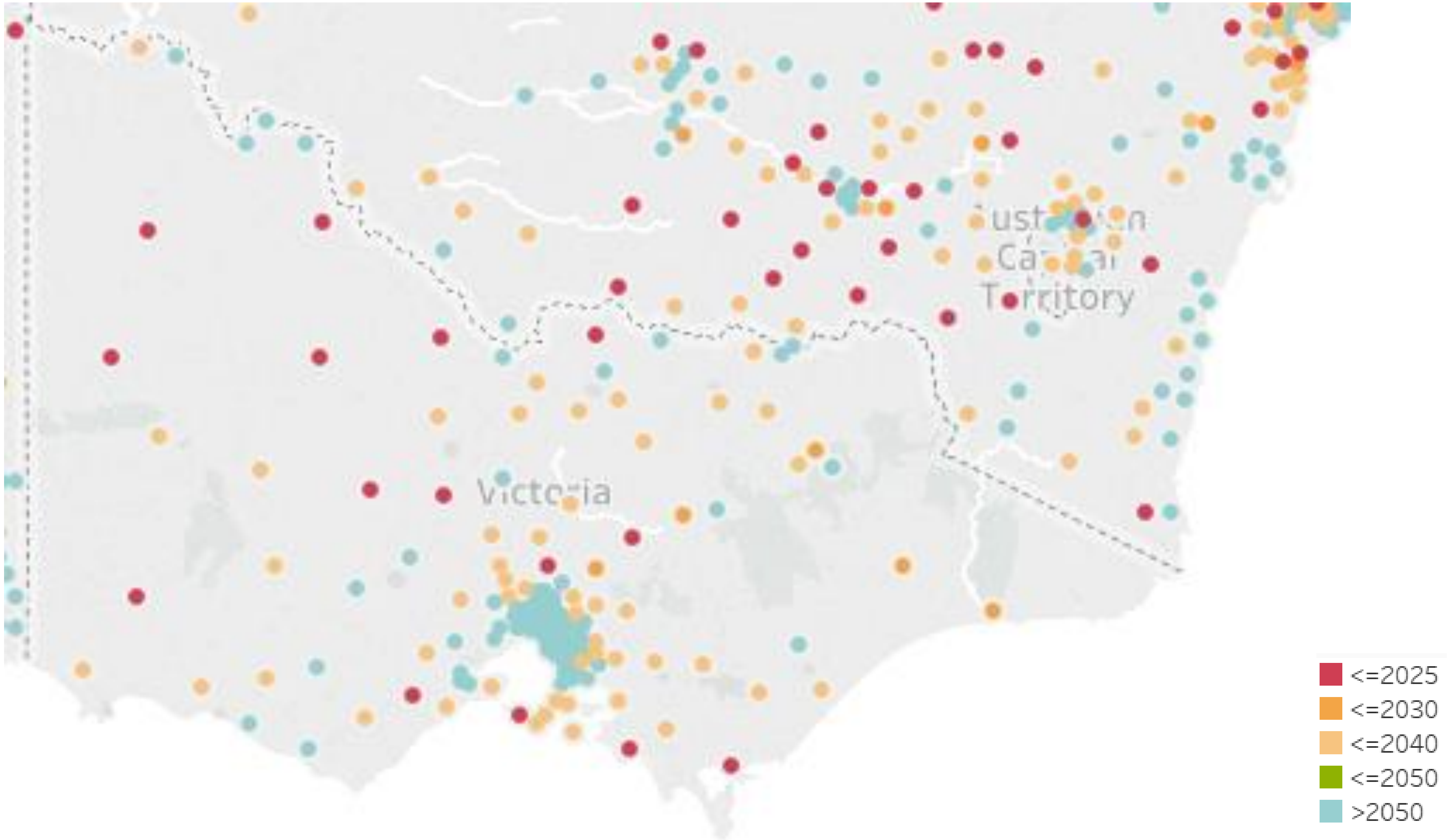
Period in which zone substation experiences negative demand: ESOO Fast



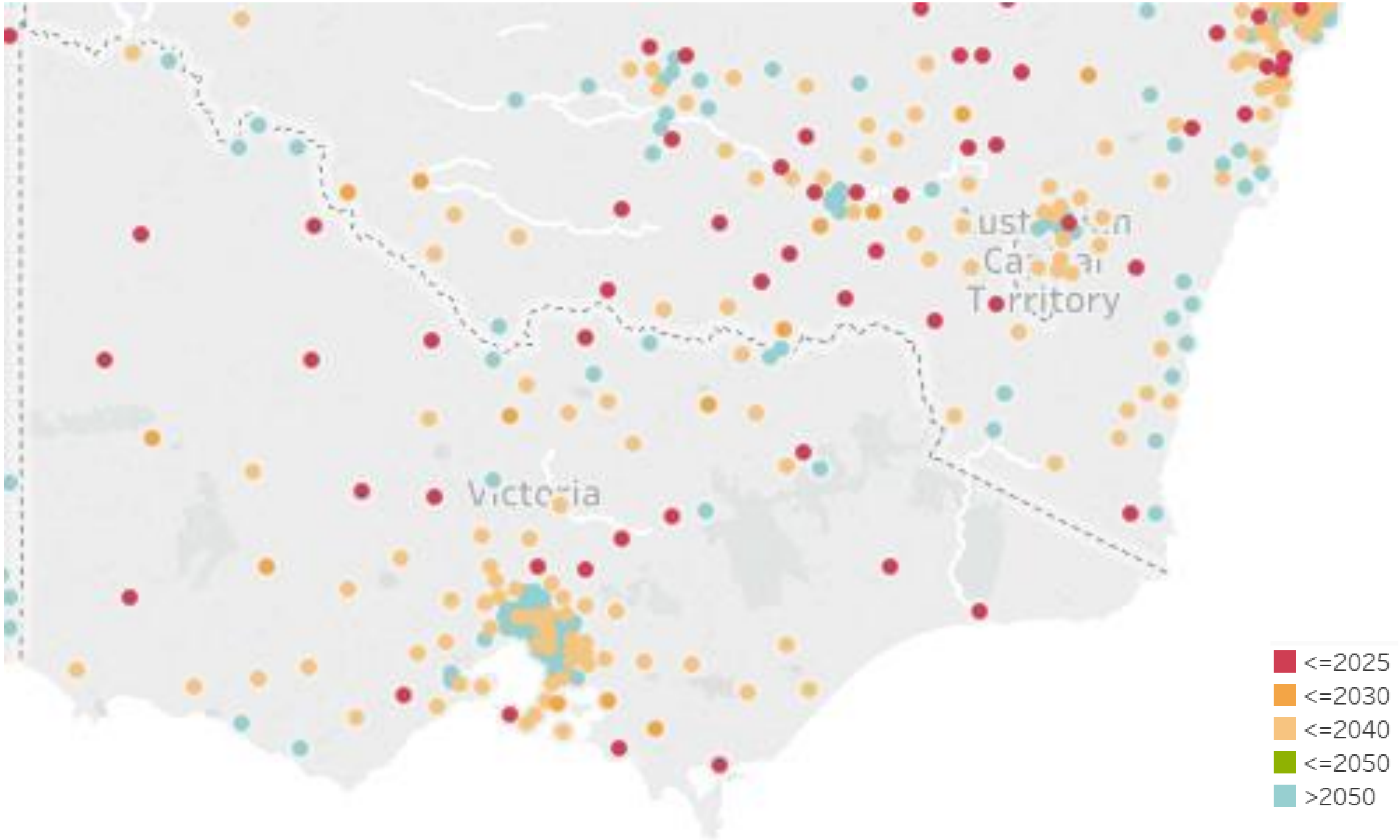
Period in which zone substation experiences negative demand: ESOO slow, Vic.



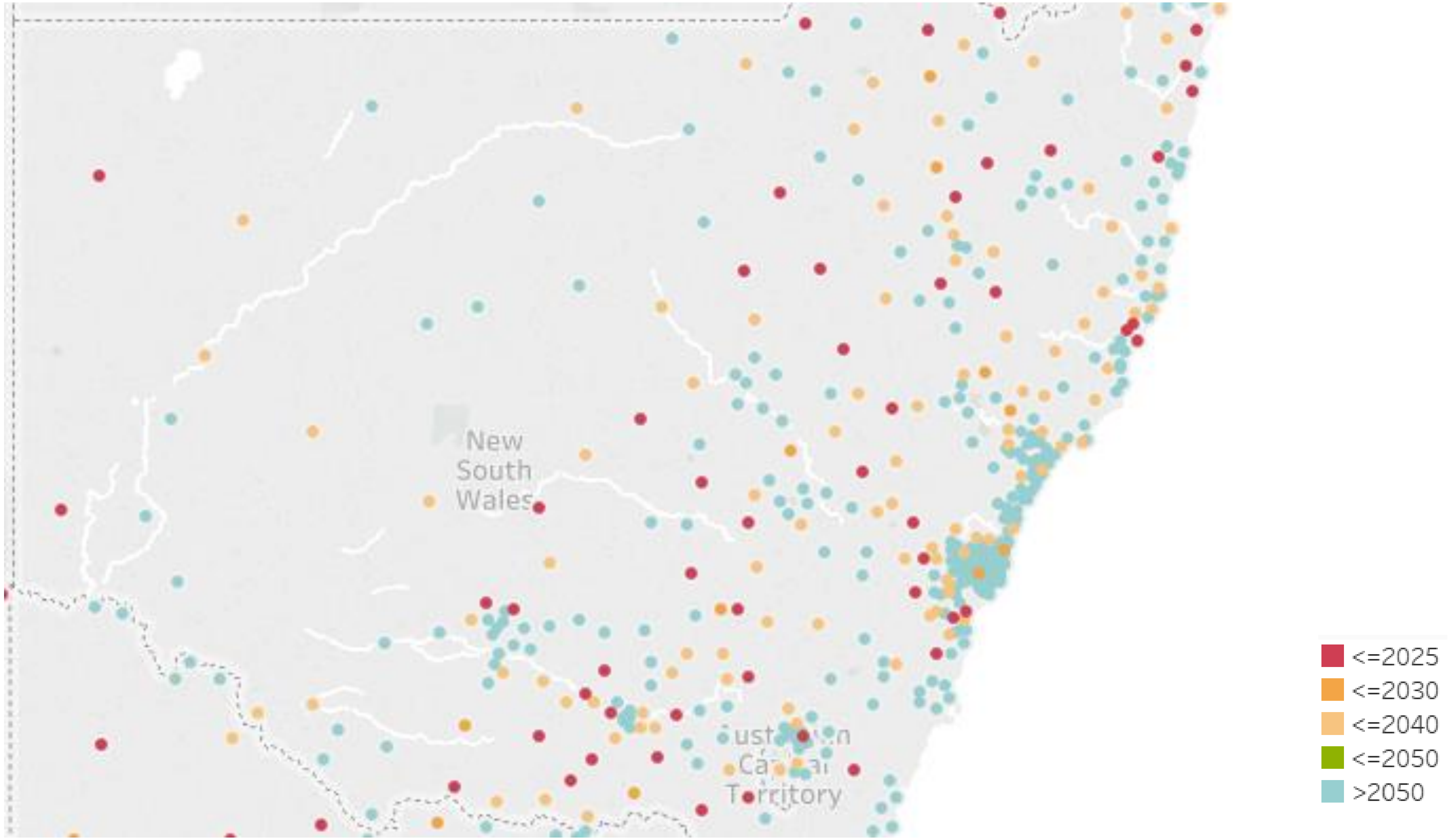
Period in which zone substation experiences negative demand: ESOO Neutral, Vic.



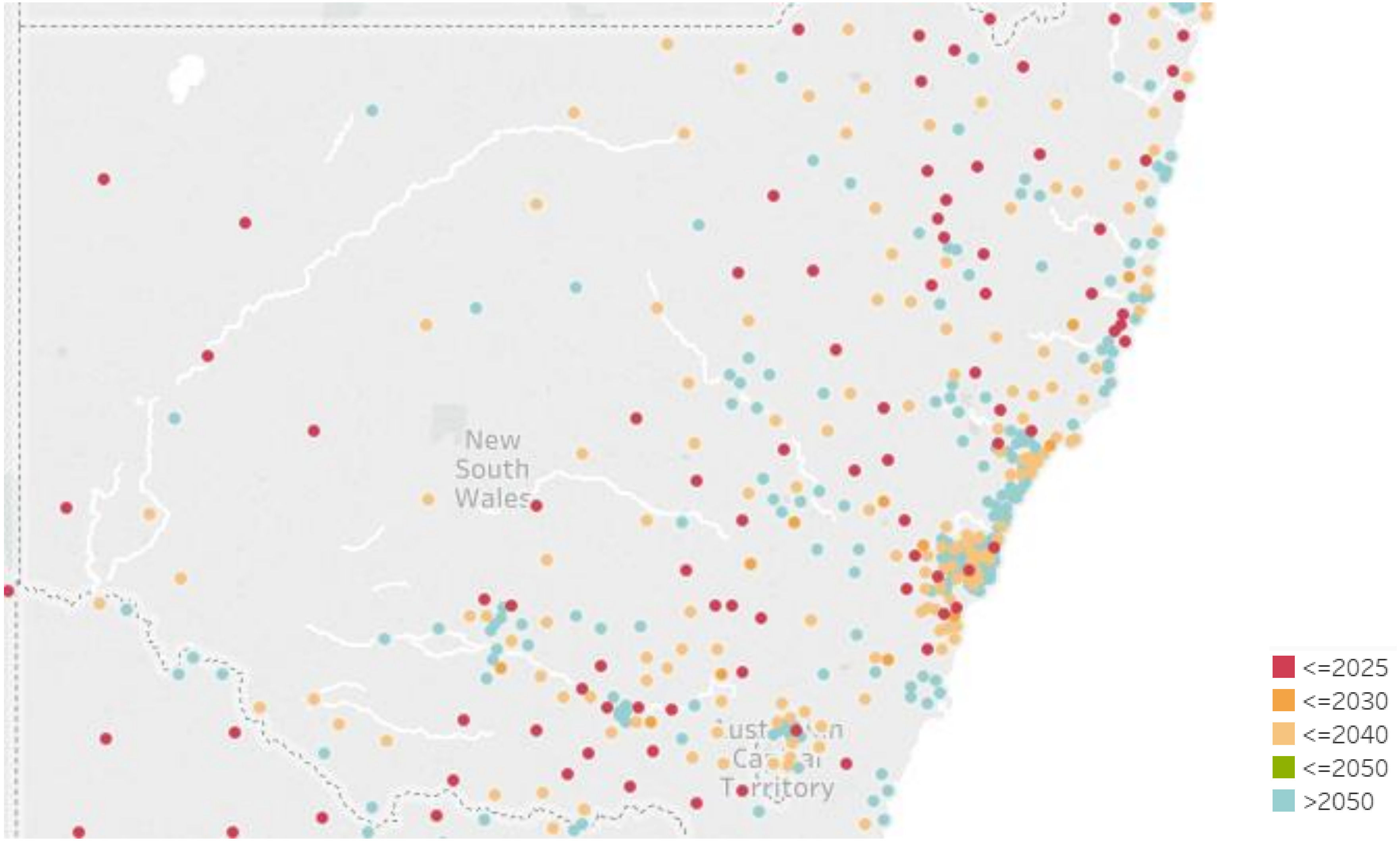
Period in which zone substation experiences negative demand: ESOO Fast, Vic.



Period in which zone substation experiences negative demand: ESOO Slow, NSW

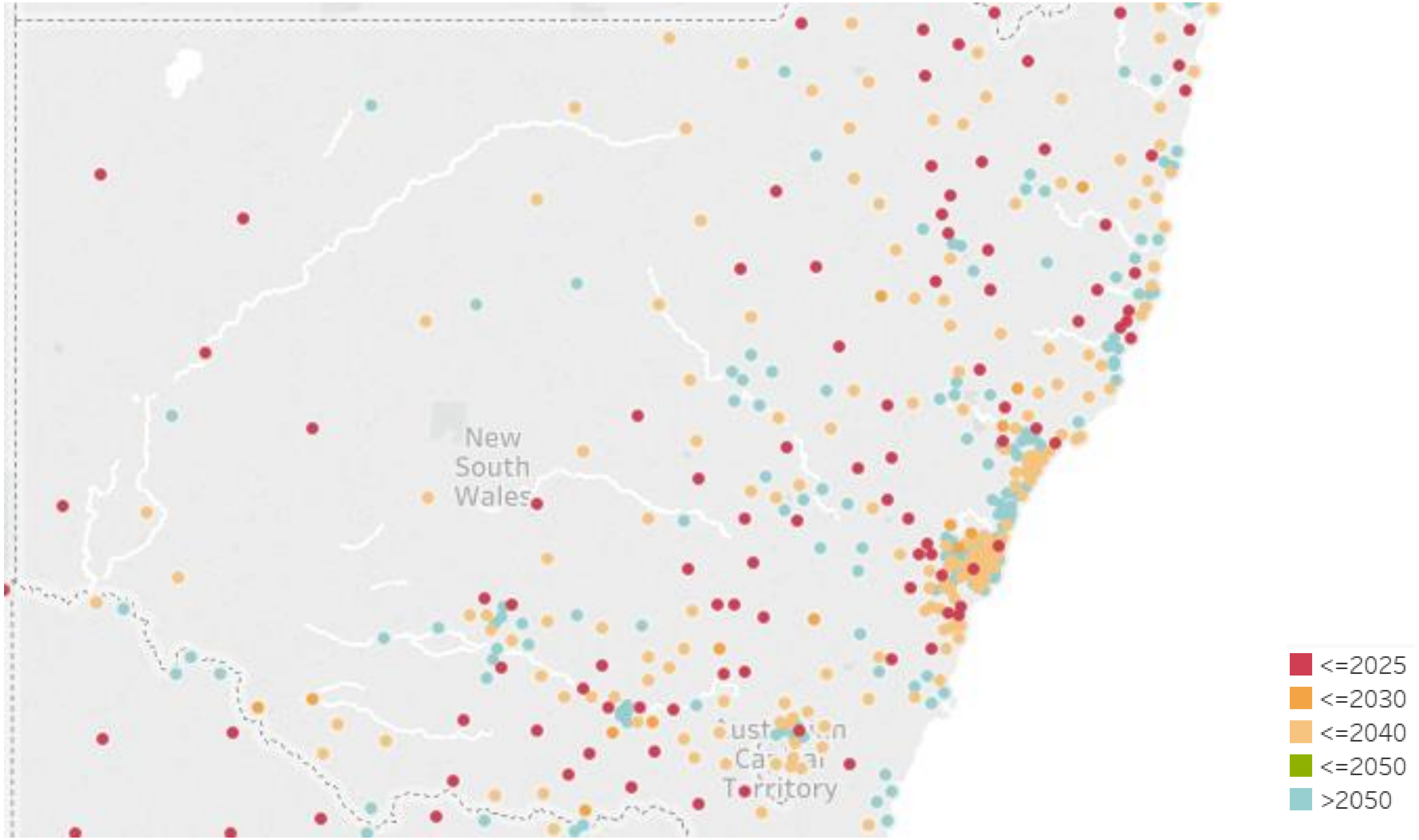


Period in which zone substation experiences negative demand: ESOO Neutral, NSW



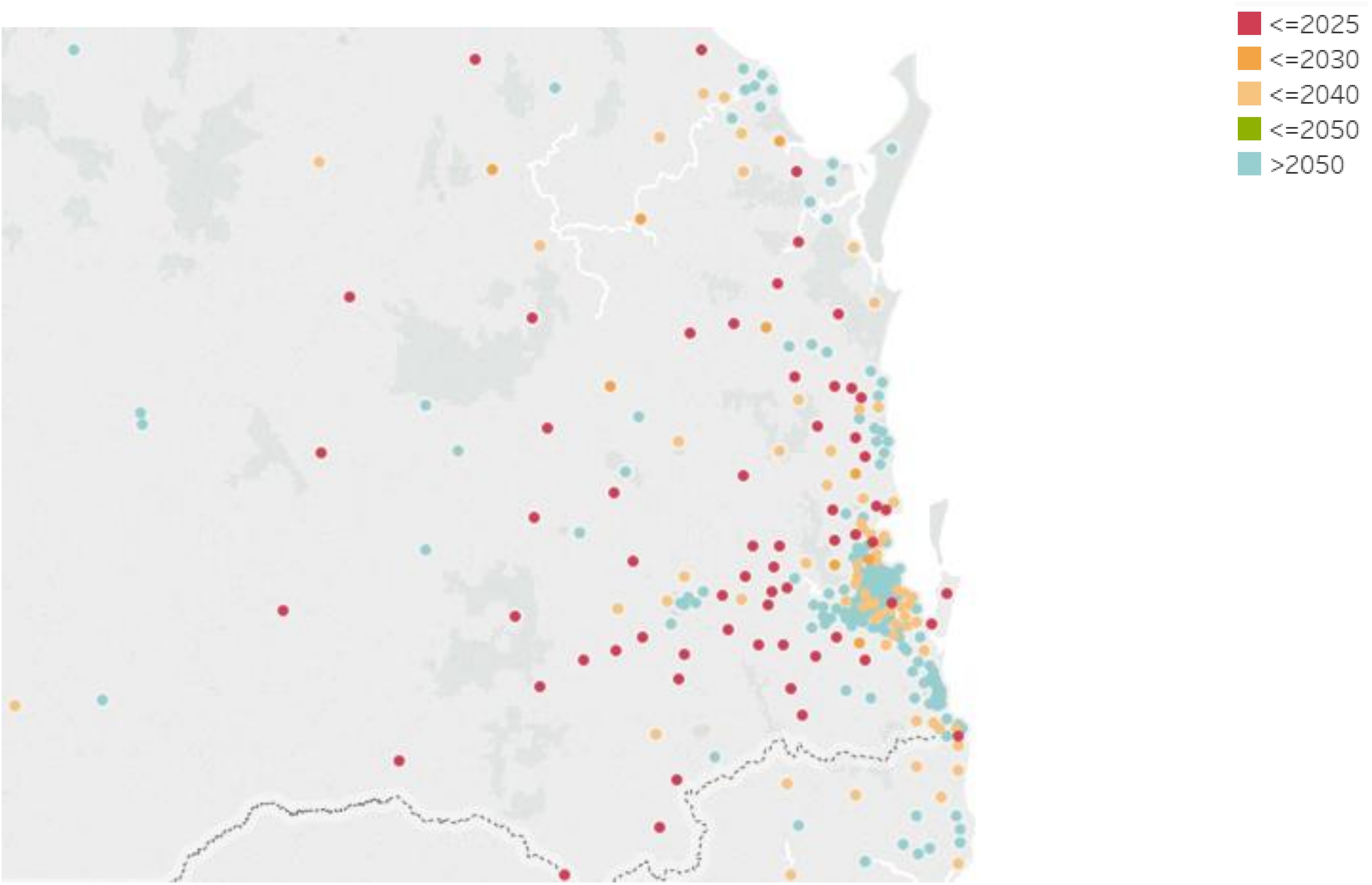
CSIRO

Period in which zone substation experiences negative demand: ESOO Fast, NSW

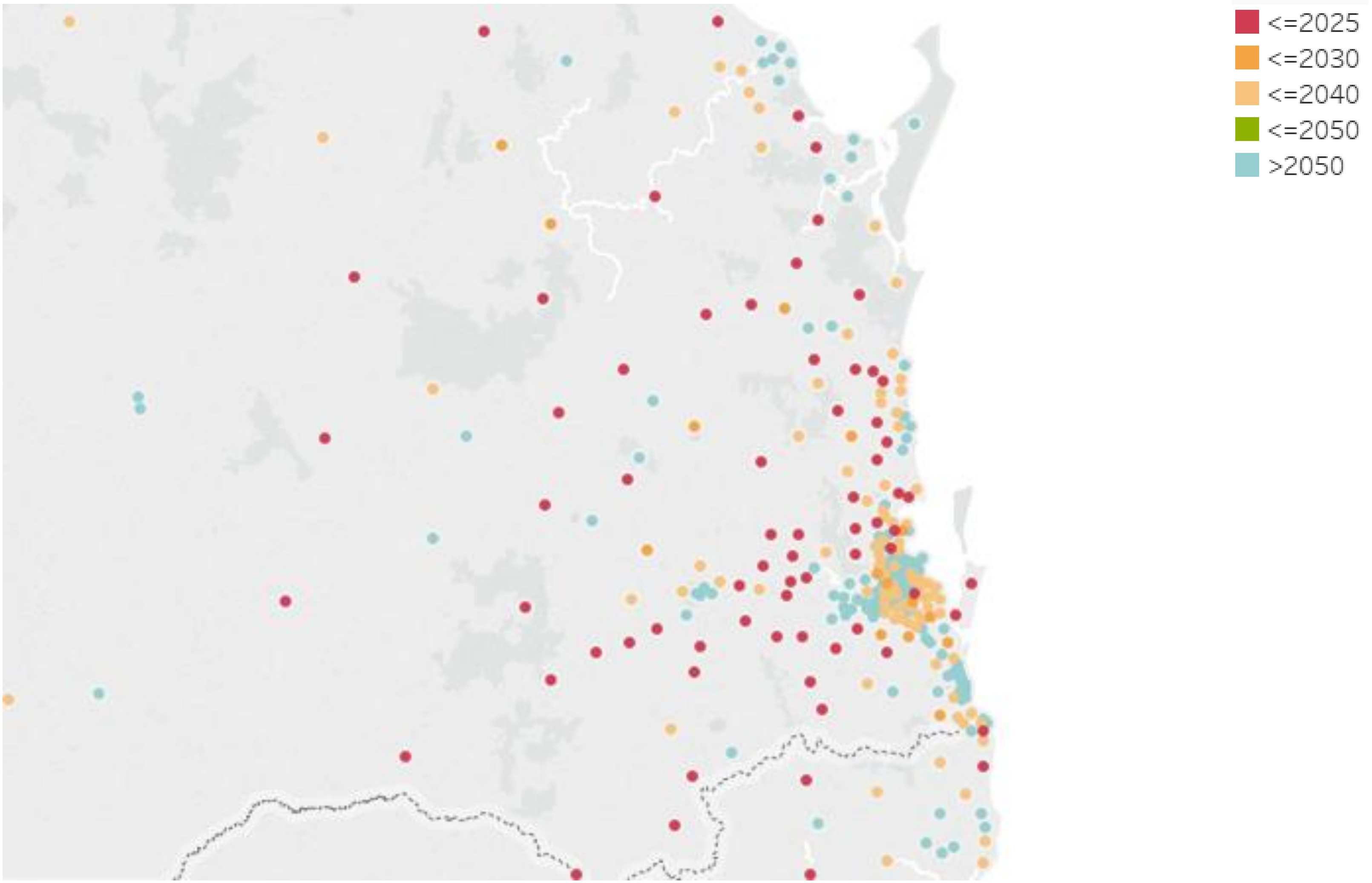


CSIRO

Period in which zone substation experiences negative demand: ESOO Slow, SE Qld

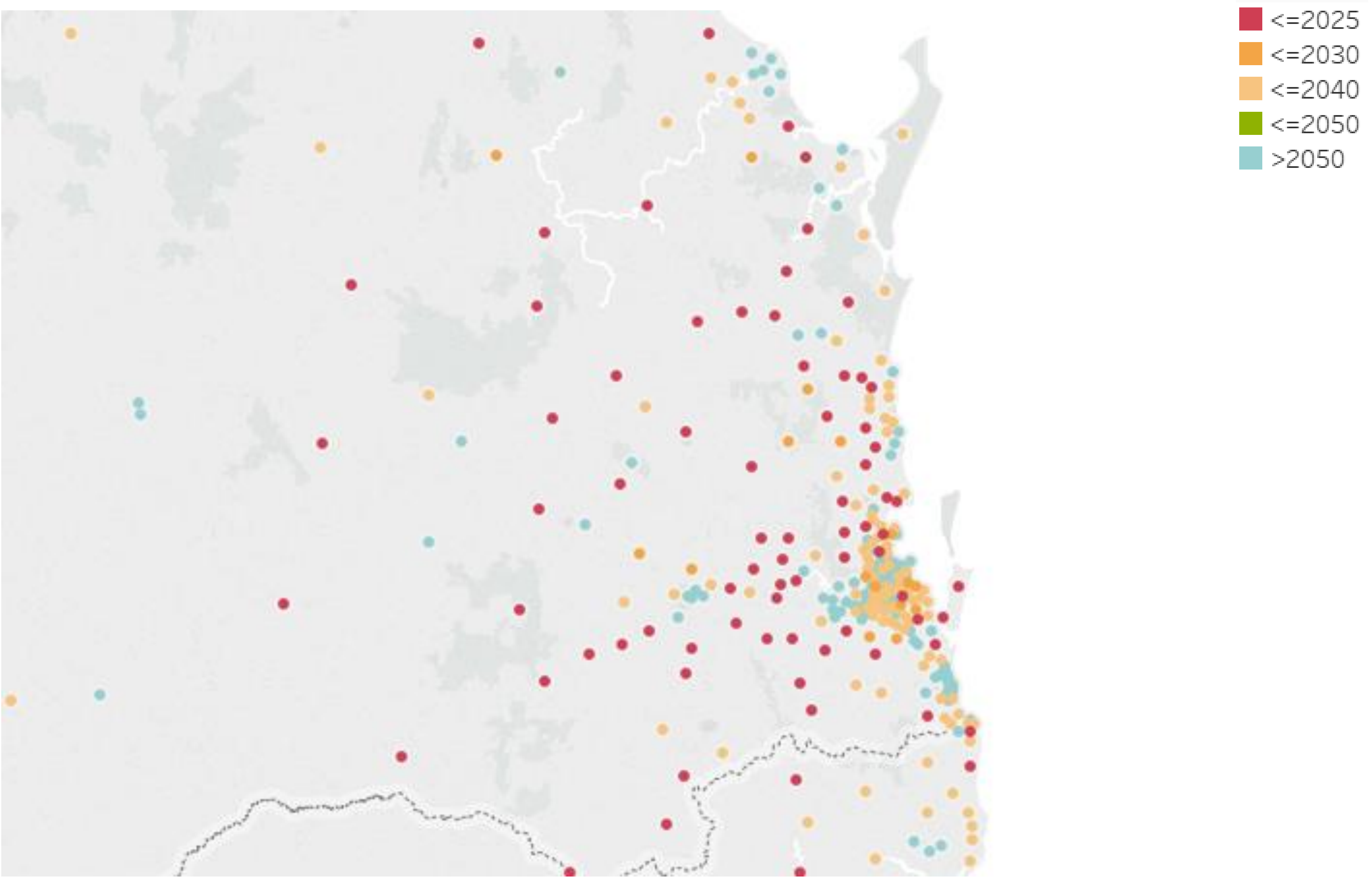


Period in which zone substation experiences negative demand: ESOO Neutral, SE Qld



CSIRO

Period in which zone substation experiences negative demand: ESOO Fast, SE Qld



Distribution network responses to DER

- Requiring new inverters to be installed with Volt-VAr response modes defined in AS4777.2
- Deploying hot water system demand to high solar output times (where available to the network)
- Offering tariffs which incentivise use of storage and diverse behaviour
- Managing voltage settings to the lower end of the range to provide more room for movement (note some states, such as South Australia, have already done this and so do not have the option to go lower)
- Capacity limits on solar (e.g. 5kW per phase)
- Smart meters at different levels of penetration

Should networks do more?

- It is not clear if the obligation to manage power quality implies obligation to enable or manage solar exports
  - Limited appetite for network investment

- Managing solar (c.f. do nothing) has distributional impacts (i.e. fairness issues):
  - Export limit on new solar customers: gifts a property right to existing solar customers
  - Complete ban on new solar: as above

- EV day time charging holds some long term promise

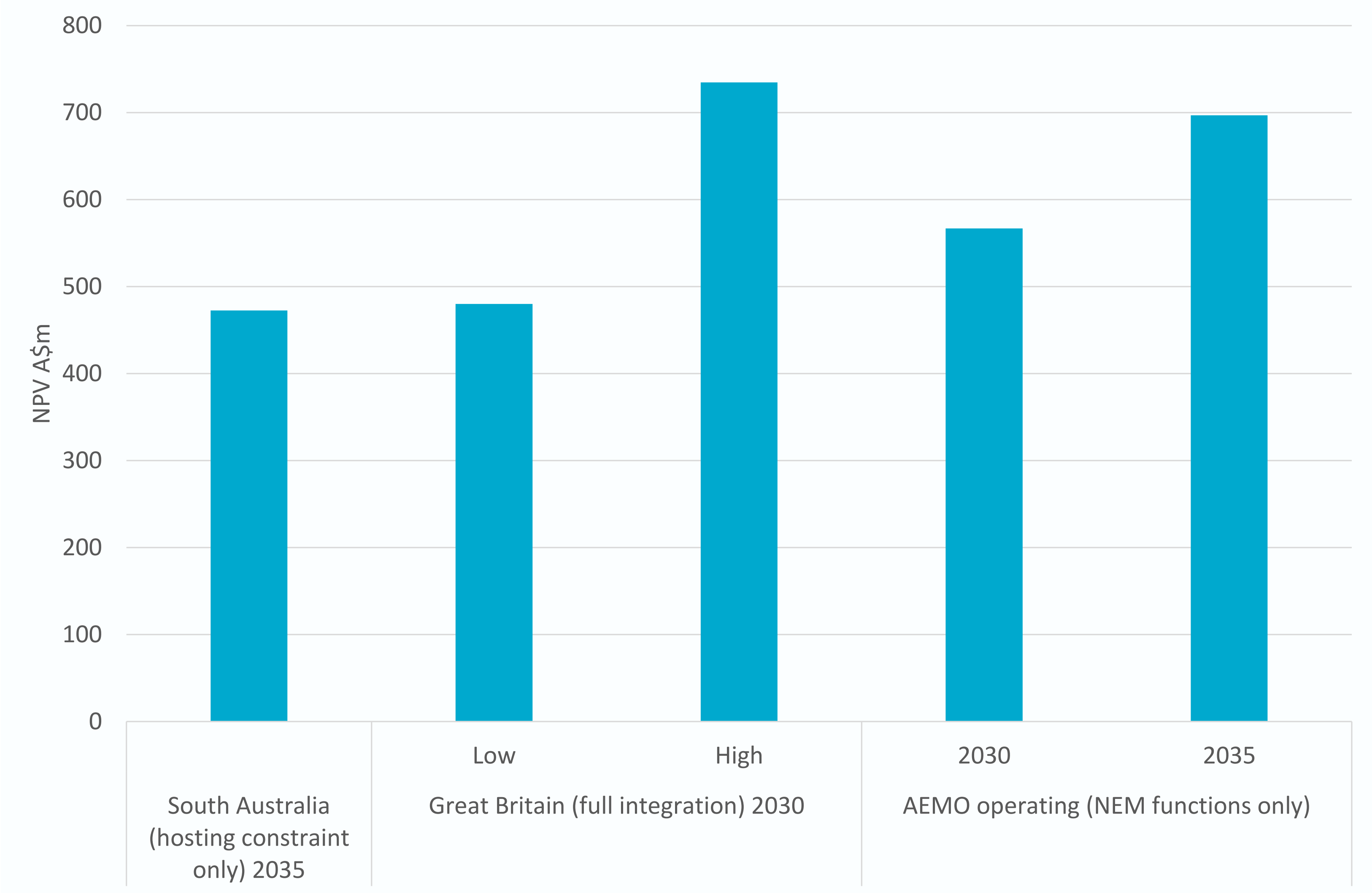
Questions for group

Is this a reasonable view of the BAU / non-centrally integrated DER world?

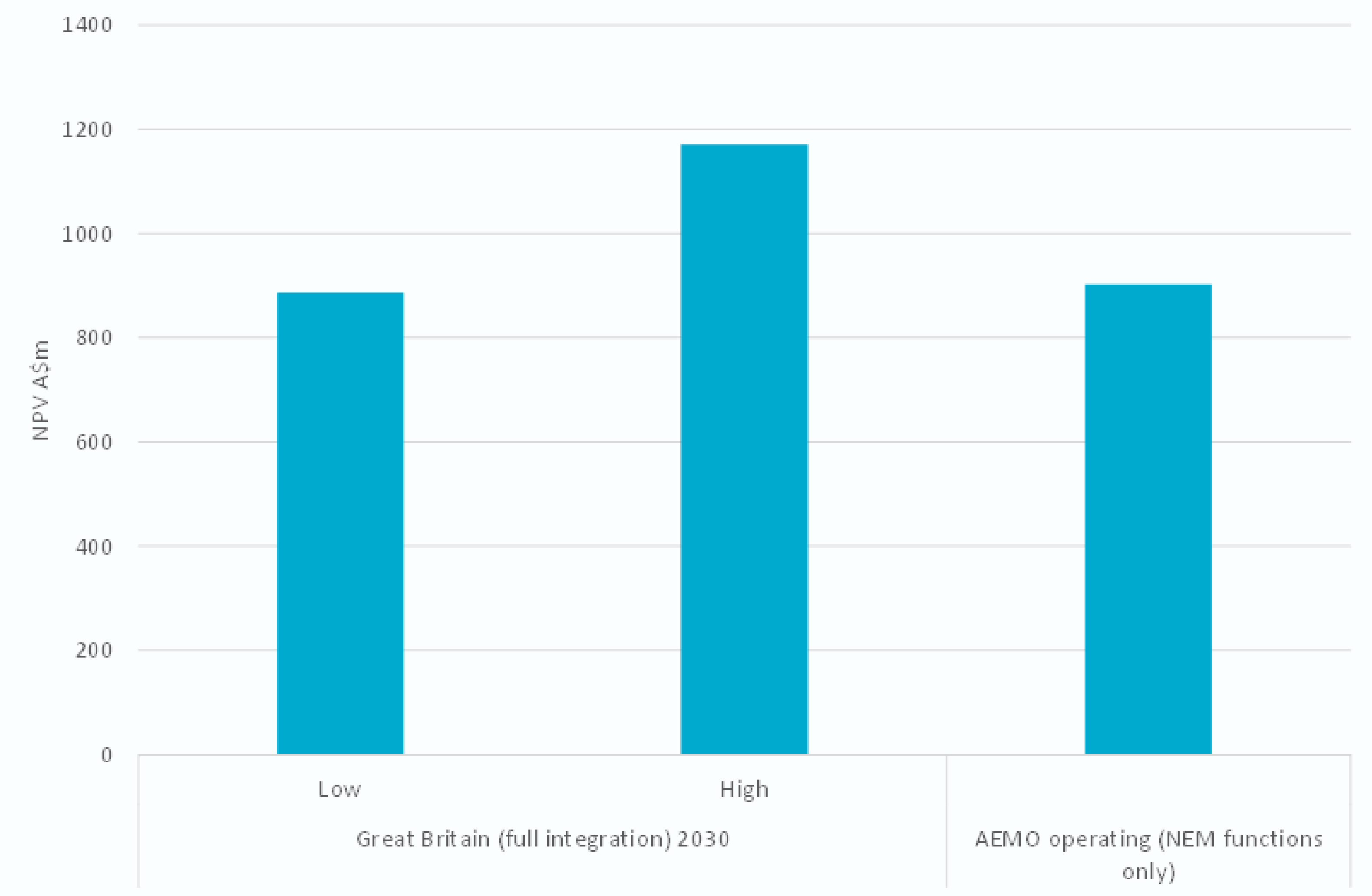
Review of existing CBA results

- Studies: ENTR, SAPN LV business case & UK Open Networks
- All converted to Australian dollars NPV
- Scaled results to an equivalent Australian-sized electricity system
  - Benefits scaled by consumption
  - SA costs by customer connections

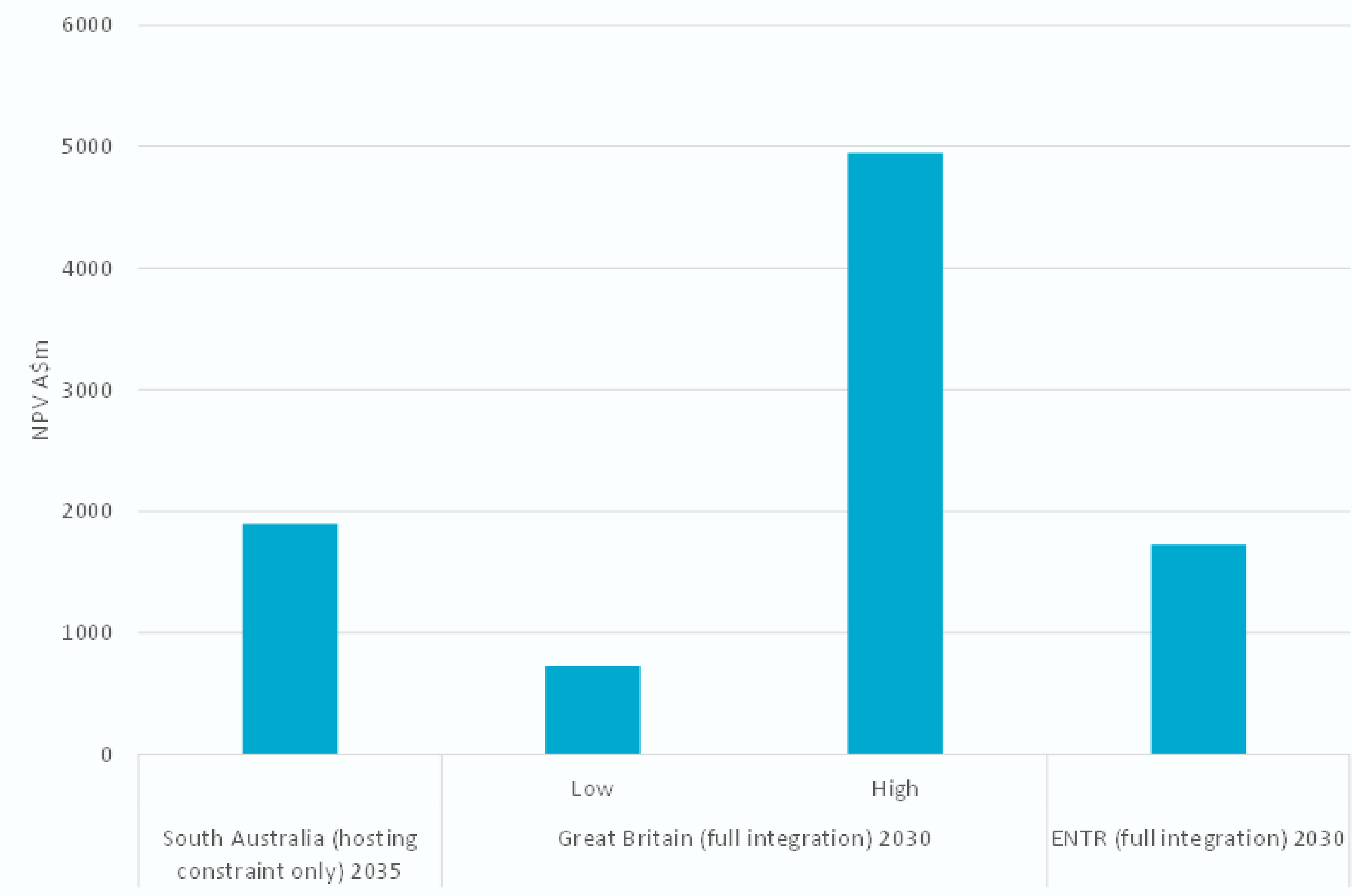
Costs in 2030/2035



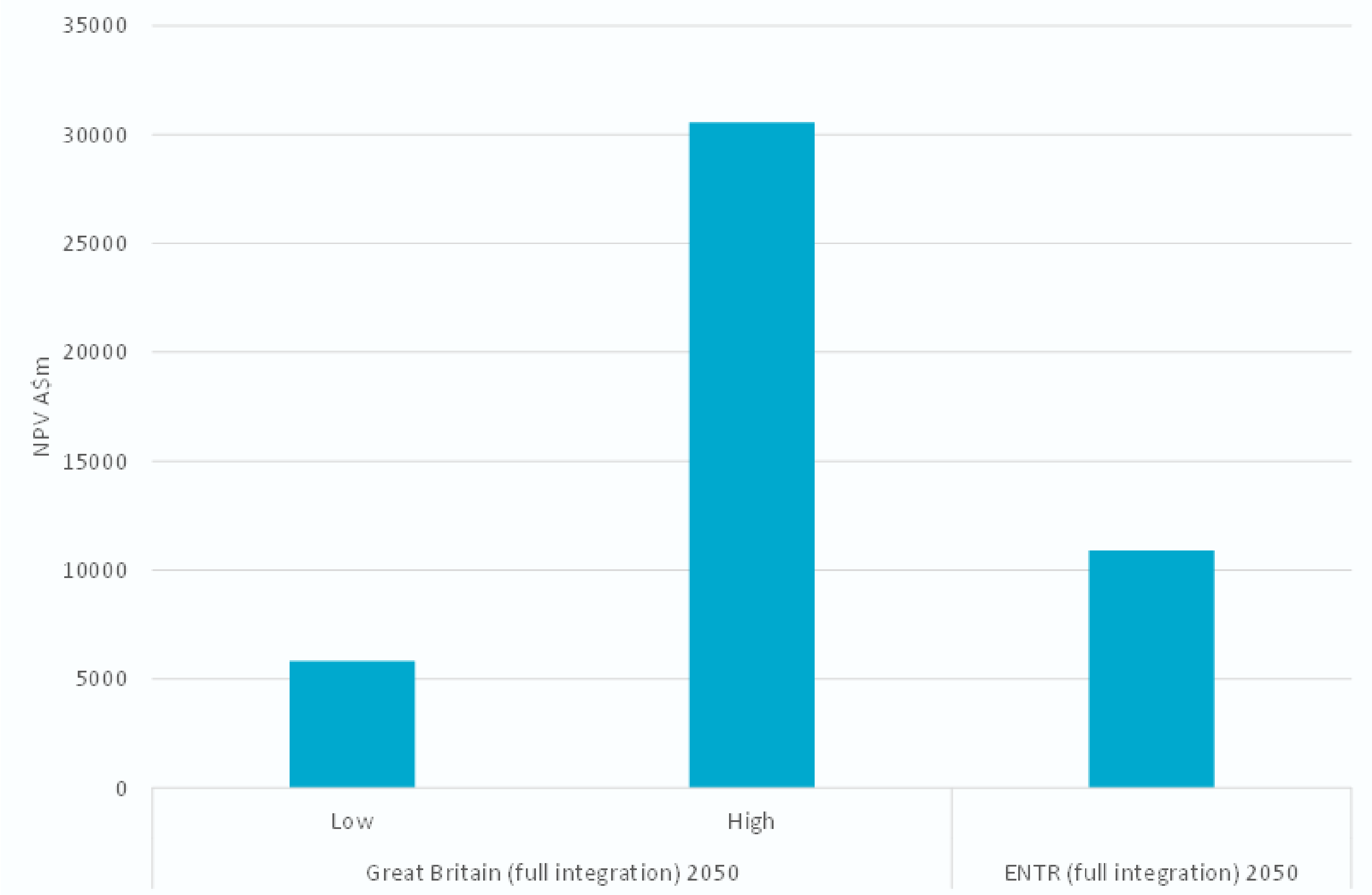
Costs in 2050



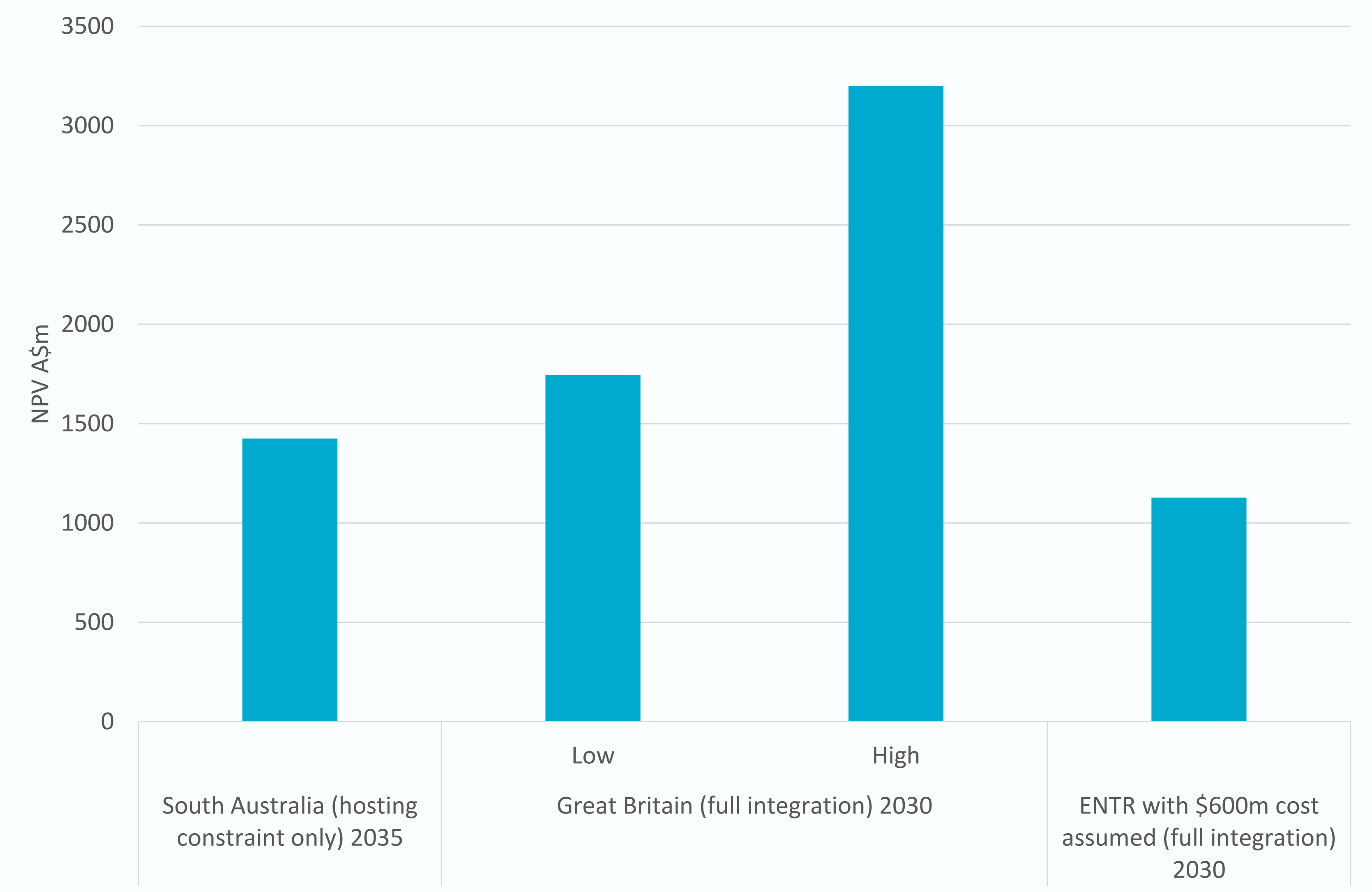
Benefits 2030 / 2035



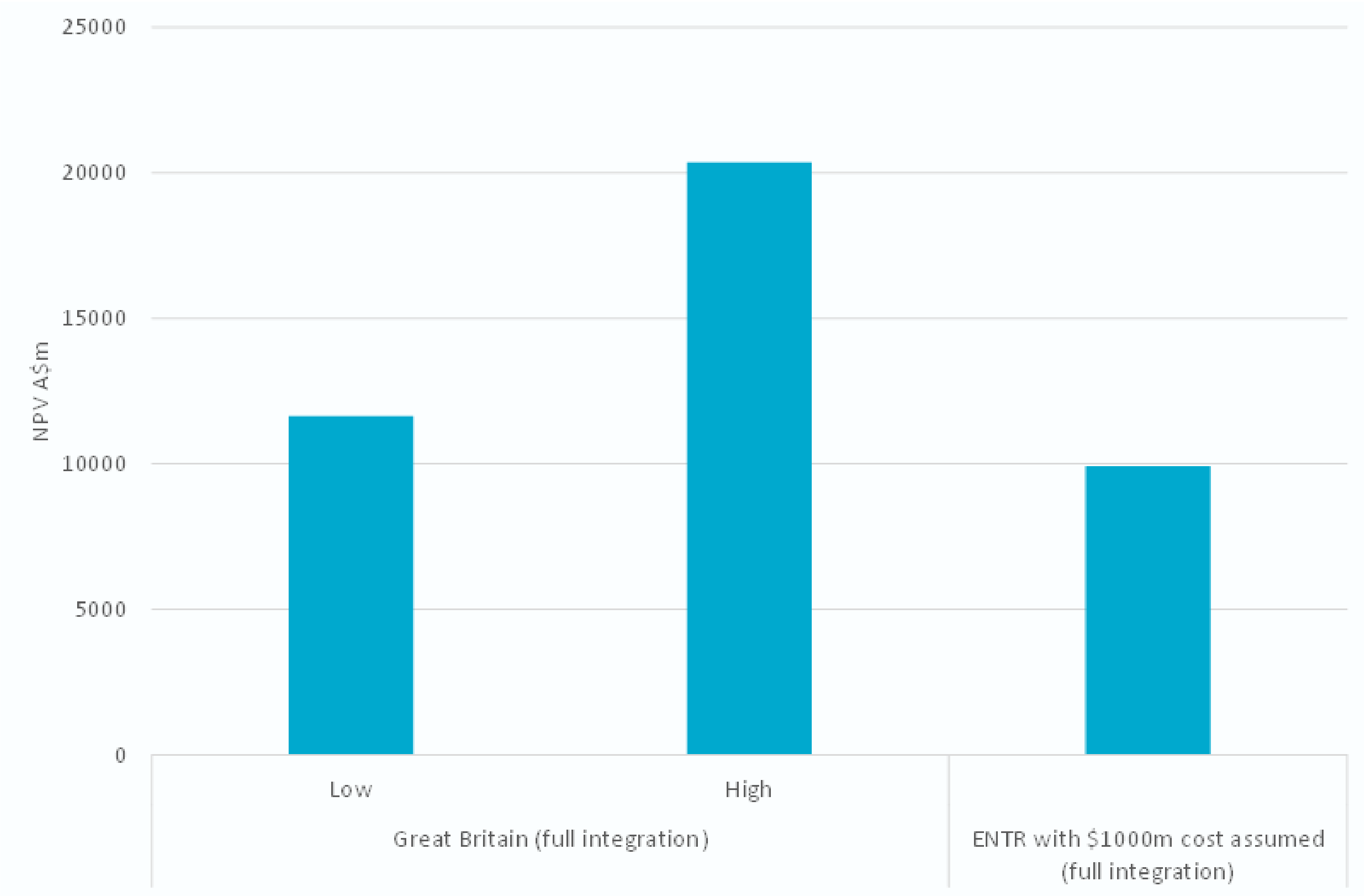
Benefits in 2050



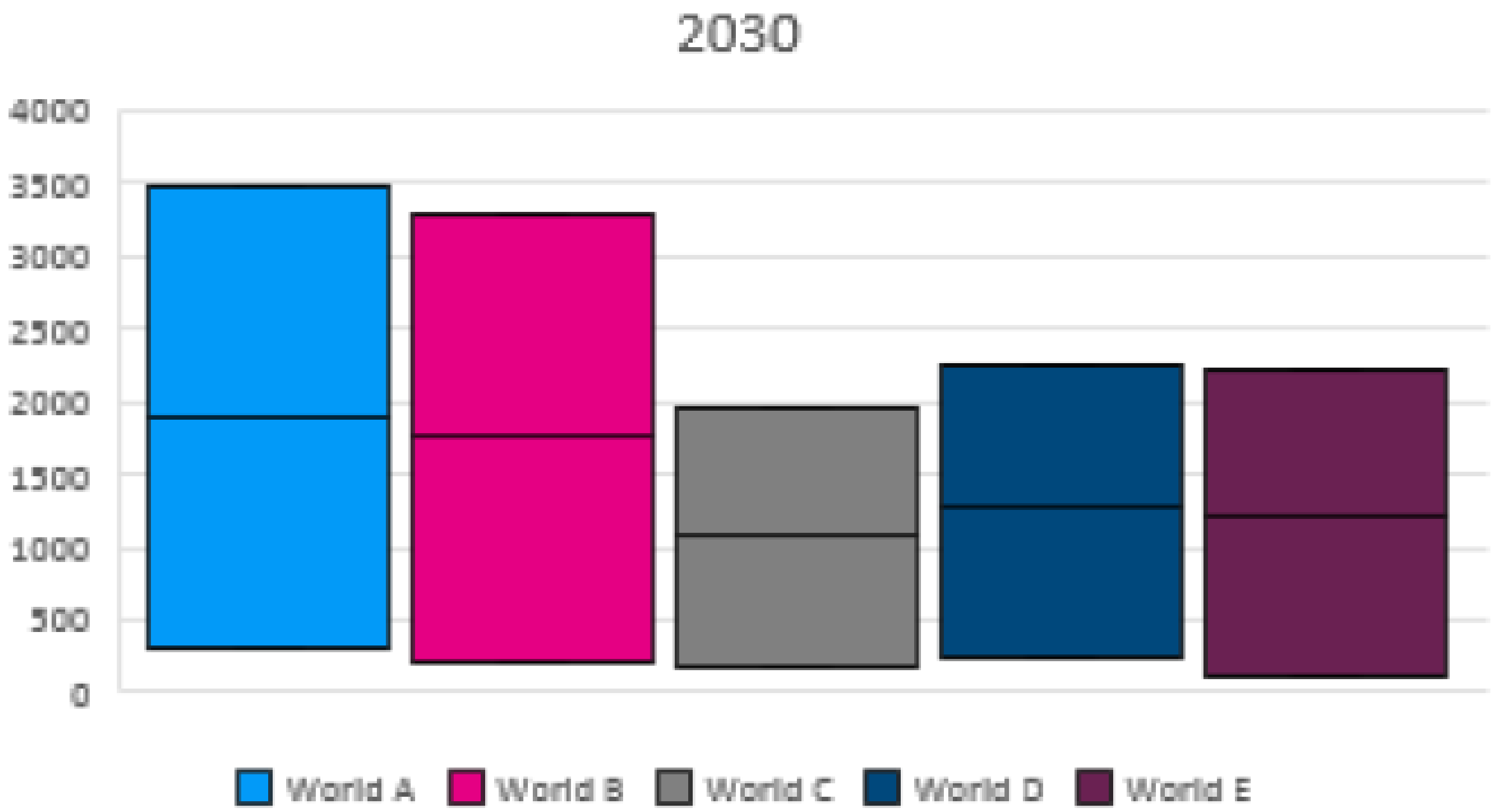
Net benefits 2030 / 2035



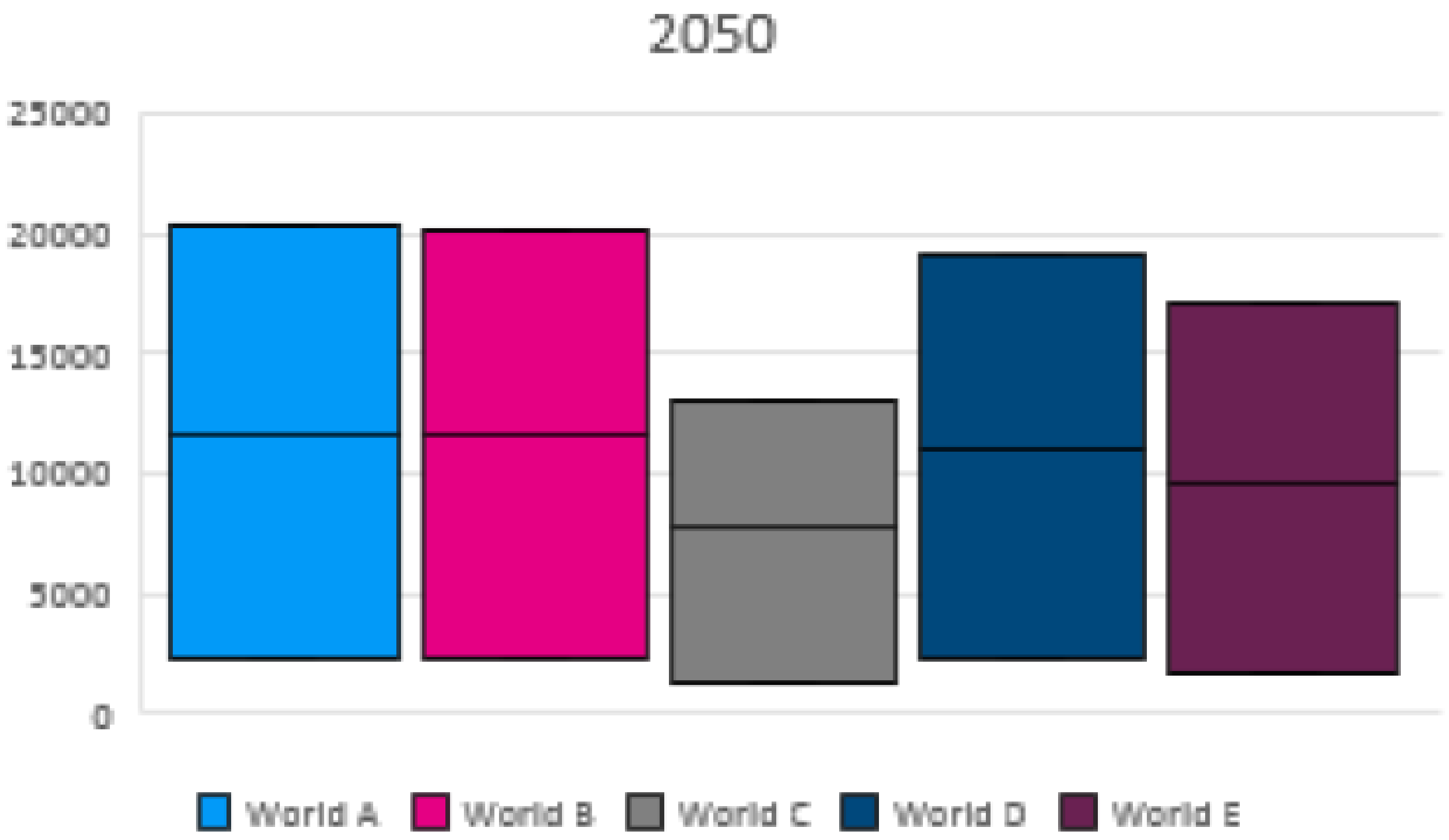
Net benefits in 2050



Net benefits UK study



Net benefits UK study



Next steps

- Scoping an updated national estimate of net benefit of DER integration with particular focus on determining the least cost / least regrets architecture
  - UK Open Networks / Baringa Partners found all worlds achieved the goals but at different timings owing to complexity

- A major technical challenge is confidence in avoided generation estimates without a LV taxonomy of Australia to calculate curtailed solar PV.

- Opportunity to adopt learnings / methods from UK study

Thank you

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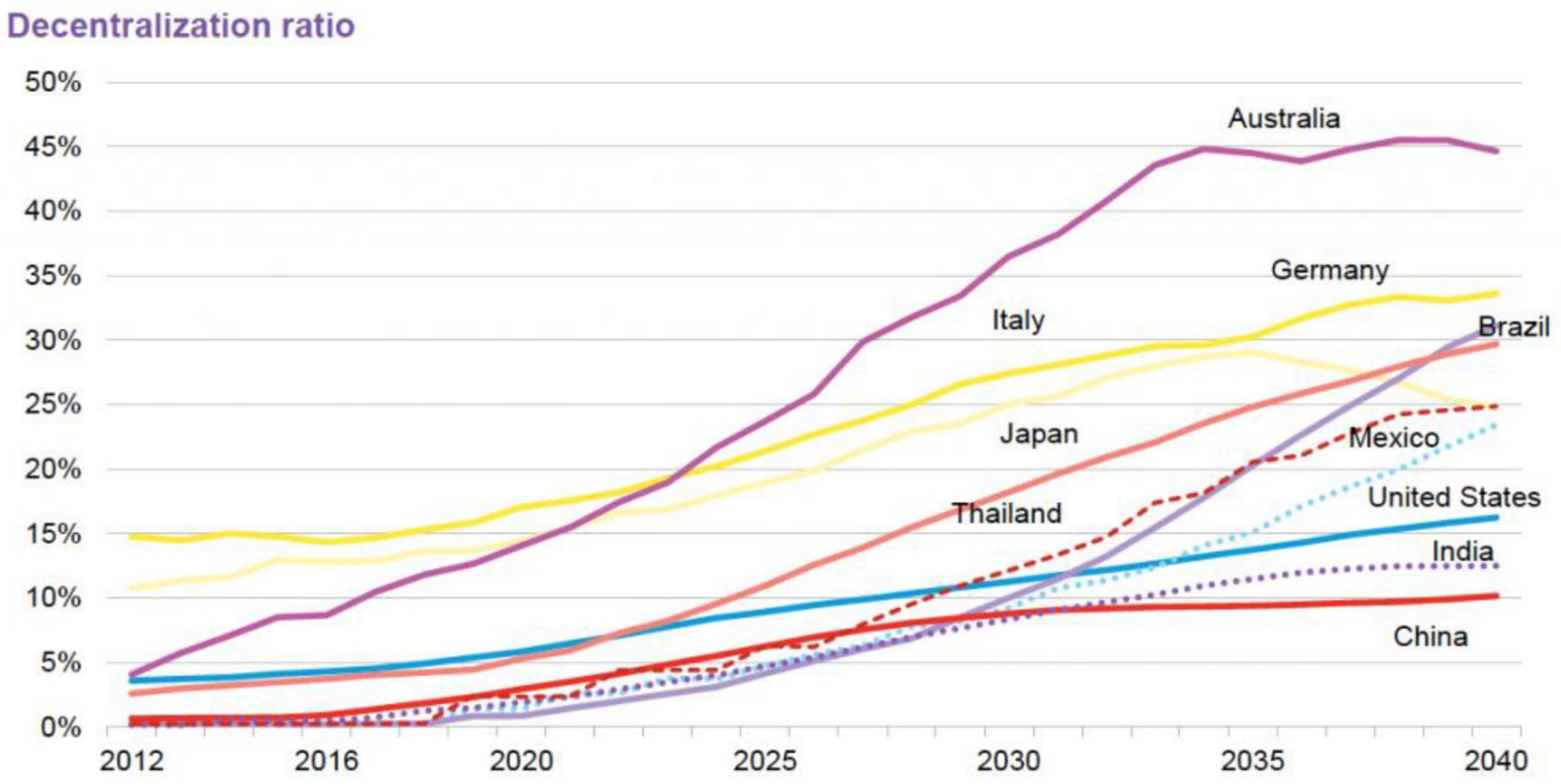
Next Steps

Publication/Activity	Date
Open Energy Networks workshops - outputs summary	Early April 2019
Publish Required Capabilities and Actions paper	Apr 2019
CSIRO Cost-Benefit analysis for Distribution level optimisation	Mar/Apr 2019
Stakeholder Workshops testing draft framework recommendation	May 2019
Final Distributed Market Framework recommendation	July 2019
Stakeholder consultation on Final Distributed Market Framework recommendations	Aug/Sept 2019
Publish Final Distributed Market Framework recommendations	Oct 2019
Distribution Market trials in QLD, Victoria and SA to test Hybrid Model variations	Ongoing

Thank You!!!

Reference Slides

A Changing World – Australia moving to a hyper-decentralized future



AEMO

Energy Networks Australia

	Description	Timing	Exposure	Risk level
Behaviour during disturbances	DER may disconnect or cease generation en masse following power system disturbances. This means that moderate disturbances may escalate into severe disturbances, decreasing robustness of the power system.	• 2019 onwards. • Aggregate behaviour is already large enough to potentially exacerbate disturbances to an operationally significant degree. • It may take multiple years to implement new standards to address shortcomings, so urgent action is required.	• Exposed during all periods with moderate to high levels of distributed PV generation. Could exacerbate faults or frequency disturbances during high PV periods.	High
Dispatchability	At present, there is no technical pathway to actively manage the generation from distributed PV systems, which is now the largest effectively the large generator (in aggregate) in the NEM. In periods when distributed PV contributes a large percentage of regional generation, AEMO may no longer be able to reduce interconnector flows. This is required under present operational practice during periods of forced outages, bushfires, or other emergency conditions. This exacerbates risks of system black, if there is a subsequent credible network failure.	• 2019 – 2024 • Partially addressed by new SA-NSW interconnector, but intra-regional dispatchability issues may also emerge (eg. Port Lincoln) • Introducing PV feed-in management will take several years, so urgent action is required.	• Exposed during periods where demand is low, and rooftop PV generation is high, if there is a co-incident emergency need to reduce interconnector flows (eg. forced outage on one of Heywood's circuits, bushfire, severe weather, etc)	High
Emergency Frequency Control Schemes	Distributed PV generation reduces the net load available for shedding under UFLS. This means that this "back-stop" mechanism becomes progressively less effective as net load decreases. Furthermore, feeders are projected to be operating in reverse flows in some periods. Under these conditions, the UFLS could operate in reverse, and act to exacerbate a frequency disturbance (rather than helping to correct it). This creates a new risk of cascading system failure.	• 2019 onwards • It is estimated that SA has already experienced some periods with very little load available for shedding. • From Dec 2019, a high number of feeders in the UFLS could be operating in reverse flows in some periods, creating a risk of counter-productive UFLS operation.	• All periods with high levels of PV generation, if a non-credible contingency event occurs. • Load available for shedding is estimated to be inadequate to cover loss of Heywood in ~0.2% of periods in 2019, increasing to ~2% of periods when synchronous condensers are installed in SA (2020).	High
System restart	At present, system restart ancillary services (SRAS) must be provided by large, synchronous units. In order to black start these units, an adequate source of stable load is required to meet their minimum loading requirements. Distributed PV reduces the amount of stable load available to support a black start of SRAS units.	• Unknown, further analysis required. • May already be periods where there is inadequate stable load available.	• Any period with a large proportion of generation supplied by distributed PV, if attempting to perform a black start. • Black start events should be very rare. • The Heywood interconnector provides an alternative pathway for restart. • SA SRAS units do not rely upon trip to house load, so it should be possible to wait until evening (when distributed PV is not operating) to commence the restart sequence.	Moderate

Common areas for action

Priority Area	Recommendation to be enacted	Description	Rationale
Aggregator development	Define the aggregator role	Clarification around the role the aggregator will play in the DER optimisation and its relationship with the energy retailer is required	In the functional specification workshops many stakeholders called for greater clarity for this role, its responsibilities including those to the customer. SGA, VPP, WDR as well as network services require a relationship with a customer that differs from the current Retailer relationship. OpEN recommends further work to define this role, included in this will be a set of common standards for DER connection and communication. ENA recently released its new Basic common connection guidelines in February.
	Aggregator and energy retailer coordinate to develop portfolios of customers	Aggregators and energy retailers can begin to further engage with active DER customers to develop a range of services that it may offer the network or market operators.	This is already starting to happen however, the gap that the project has identified is the cross over between the product and services DER can provide and the future network and system requirements prior to the development of portfolios of customers. The ability for DER to provide these services will be driven by the mechanisms for pricing (ie market or other procurement process) and the ability for a DER owner to access these markets AEMO has begun work on understanding the services that a future system and network requirements and the various supply and demand side assets that can provide these services (next slide).

Possible Key actions to Trial

Priority Area	Recommendation to trial	Description	Rationale
Wholesale market for DER integration	Aggregator and energy retailer apply to participate in the wholesale and FCAS services markets	All of the frameworks anticipate that DER, or aggregated portfolios of DER, will participate as a Market Ancillary Services provider, Market Customer or Market Generator.	While this is happening in part, the ability of Aggregators to participate in markets visible to AEMO is not consistent. The VPP Demonstrations are a key action necessary to allow further DER participation in energy and FCAS markets. The AEMC's WDR rule change process will also help to shed light on the process of wholesale market integration for DER as it is anticipated that this will clarify the roles of Retailer and Aggregator; and plans to address at least in part; issues surrounding the introduction of any multiple trading relationship regime.
	Aggregator and energy retailer dispatch customers in response to market signals or contractual arrangements	The creation of communication infrastructure between aggregators, energy retailers and the market platform to facilitate the use of real-time dispatch signals is needed to unlock DER value A framework for dispatch at a Wholesale and Local Level will need to be developed including standard communication protocols and a common bidding process and common infrastructure that can be then transposed by Aggregators/Retailers to send signals to DER.	While this may be occurring in some trials this is not done to any standard, so as a minimum some sort of common protocol is required. This will encourage competition by not "locking in" customers to proprietary protocols. Further issues include the 2-sided nature of battery capability which cannot operate seamlessly in the market. To this end AEMO is working with stakeholders involved in the VPP Demonstrations trial, as well as other ARENA funded projects to develop common API specifications in order to avoid "rail gauge" issues for Aggregators and Retailers looking to engage with multiple DNSPs and trials.

Possible Key actions to Trial

Priority Area	Recommendation to trial	Description	Rationale
Network services market for DER integration	Adjust market rules to establish a network services market	A trial area for a distribution network services market could be established: to gauge the costs and benefits such a market would bring; to better understand the appetites of customers, aggregators, energy retailers and network operators to participate; and to determine best practice going forward	OpEN agree that a further definition and trialling of a market for network services is required prior to the need to change market rules. Currently DNSPs can contract and pay for these services directly and the need for a market and the design of any market will need to be determined. Trials of ability of DER to provide Network Services are already underway thanks to ARENA funding. One such project Networks Renewed has UTS working in AusNet and Essential Distribution regions to test the ability of DER to provide both active and reactive power to help manage network voltage issues. Further trials of this nature will be required to test the ability to communicate with DER, the nature of DER response and its effect on the LV and HV voltage levels.
	Rules or guidance is created on the use of bilateral network services contracts out with the market platforms	Bilateral contracts for network service must be coordinated with market operations and rules established setting out any exclusions on the use of bilateral contracts out with an optimised market platform	Prior to any market for network services, guidance for how contracts for services are struck and dispatched will help AEMO, networks and aggregators operate the system network and manage there own portfolios respectively. This recommendation concerns the minimum level of visibility the market and network operator may need to ensure the reliable operation of the system and network.

Possible Key actions to Trial

Priority Area	Recommendation to trial	Description	Rationale
Network services market for transmission customers	AEMO dispatches the T-NSCAS, wholesale and FCAS services markets	AEMO may play a role in actively managing T-network constraints by trailing a network services market open to transmission customers	The Function Specifications workshops identified the need to incentivise and procure network services from DER. The OpEN team wants to ensure that the new Network Services market is described in a manner to ensure that it is not incorrectly conflated with existing Network Support and Control Ancillary Services (NSCAS). This implies a future where these services are co-optimised with Wholesale and FCAS markets. An example of a trial running in the UK is the National Grid/UK Power Networks Power Potential trial which uses an auction mechanism for DER (and other types of assets) to provide active and reactive power to help manage voltage and improve capacity on the Transmission Network.

Possible Key actions to Trial

Priority Area	Recommendation to trial	Description	Rationale
Pricing signals	Pricing signals	Local pricing signals can be developed to manage customer behaviour out with a market or contractual obligation. Signals can be market driven (i.e. based on the wholesale price of electricity), network driven (i.e. based on local constraints for import / export) or a combination of both. Trials may be undertaken to better understand customer response to pricing signals and their position in the transition to a Distributed Market framework	OpEN have identified pricing as a key gap in the consultation paper and frameworks identified in the process. Pricing will play a key role in the future customer propositions for DER and may hinder Distribution level optimisation if not designed in the correct manner. We would welcome the opportunity to work closely with AEMC or AER on explore these issues. One example of an approach being taken in the California ISO is the introduction of a specific DER tariff for aggregators looking access markets administered by the ISO. This may be best done in a separate paper or as part of the DEIP process.

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APPENDIX

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FRAMEWORKS – FURTHER DETAIL

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Market arrangements	• There is a central market comprised of wholesale and ancillary services markets (i.e. FCAS, NSCAS) that is organised and operated by AEMO • There is a single central market platform that facilitates the direct access of market participants to the different markets enabling "value stacking" for energy resource owners • The central market platform collects bids and offers from market participants, including DER via aggregators/retailers, and makes them available to AEMO for whole system optimisation
AEMO	• AEMO organises and operates the central market and is responsible for the dispatch and settlement of the market and system security and reliability across the five interconnected states through T- and D-network connected energy resources • AEMO optimises the dispatch of energy resources considering T-network and D-network constraints • AEMO has a central role in coordinating how DER are used by the system as a whole including their procurement, dispatch and settlement for D-network constraint management • AEMO has the commercial relationship with DER via aggregators/retailers and is responsible for the financial settlement of market participants
DSO	• The DSO is responsible for the development and operation of the electricity distribution network following an active network management approach • The DSO provides DER with static operating envelopes based upon the technical capability forecast of the D-network to accommodate DER dispatch in order to inform DER bids and offers into the central market • The DSO exchanges information with the AEMO, such as network operational status and forecasts, to facilitate the consideration of distribution network constraints and the development of dynamic operating envelopes in the whole system dispatch process
Aggregator / Retailer	• The aggregator/retailer combines different DER and offer their aggregated output as system services. The aggregator/retailer provides bids and offers directly to the central market platform based upon their provided operating static and/or dynamic envelope. The aggregator/retailer activates DER based on dispatch instructions received from AEMO via the central market platform
Distributed Energy Resources	• Power generation technologies (including electric energy storage facilities) and end use electricity consumers (e.g. industrial and commercial) with the ability of flexing their generation or demand (i.e. demand side response) in response to control signals that are directly connected to the electricity distribution network. DER provide energy and network services to system operators (e.g. AEMO, DSOs, etc.) for electricity system balancing and network constraint management
Customer	• Domestic or industrial end-use electricity customers that are energy conscious and therefore have invested in off-the-shelf low carbon products (e.g. solar panels, heat pumps, electric vehicles, electric battery storage) to reduce energy bills. These customers may be exporting to and importing from the D-network and would seek to benefit from retailer's time of use tariffs; and/or • Domestic or smaller non-domestic end-use electricity customers with little or no interest in low carbon products or time of use tariffs

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Advantages	Disadvantages
• All market participants interact with a single entity (i.e. AEMO), via the central platform, that acts as an independent, neutral and transparent market facilitator • More moderate regulatory change required (compared to other frameworks) as AEMO already performs this type of role for wholesale and frequency, and it can be seen as an extension of the wholesale and FCAS markets • A central market allows for streamlined standardisation of processes and procedures • Aggregators operating across multiple DSO regions may increase competition for service provision and potentially reduce system costs • Procurement, dispatch and settlement of DER for provision of system services is organised and operated by a single entity (i.e. AEMO) • It allows for synergies between T- and D-network requirements to be identified through coordinated procurement processes, avoiding the risk of inefficiency through separate procurement of the same service from the same DER, or from different DER, where that DER could have solved both issues. • It allows for the management of conflict between system service delivery requirements and distribution network capabilities as distribution network management issues can be explicitly accounted for in the procurement and dispatch processes through exchange of relevant information	• The expanded role for AEMO, requiring a wider range of resources, may have implications for AEMO's current funding model as it may need to be adapted to fit this expanded role. • The DSO does not exercise control over the DERs connected at the distribution network that are procured and dispatched by AEMO

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Market arrangements	• There is a central market comprised of wholesale and ancillary services markets (i.e. FCAS, NSCAS) for energy resources connected at the T-network that is organised and operated by AEMO • The central market collects bids and offers directly from T-network connected market participants and indirectly from D-network connected market participants via the DSOs, to facilitate AEMO's whole system optimisation process • There is a local market for DER that is facilitated by the DSO of the respective geographical region via a local market platform • The local market platform collects bids and offers from DER via aggregators/retailers for T- and D-networks constraint management and electricity transmission system balancing • Both central and local markets facilitate the direct access of market participants to different markets enabling "value stacking" for energy resource owners
AEMO	• AEMO organises and operates the central market and is responsible for the dispatch and settlement of the market and system security and reliability across the five interconnected states through T- and D-network connected energy resources • AEMO assesses all bids and offers and optimises the dispatch of energy resources considering T-network and D-network constraints • AEMO optimises dispatch across the D-network boundary based on an aggregated dispatch schedule technically and commercially agreed with the DSO for every DER area
DSO	• The DSO is responsible for the development and operation of the electricity distribution network following an active network management approach and for the organisation and operation of the local market for DER • The DSO provides DER with static operating envelopes based upon the technical capability forecast of the D-network to accommodate DER dispatch in order to inform DER bids and offers into the local market • The DSO collects bids and offers for DER service provision from the local market platform. The DSO converts DER bids into an aggregated bid stack per DER area and tests these against a dynamic operating envelope based on the network state in order to ensure the activation of these DER does not unduly constrain the distribution network. The DSO passes the aggregated bids to AEMO for whole system optimisation • The DSO allocates dispatch to individual aggregators/retailers based on the dispatch schedule across D-network boundary resultant from AEMO's whole system optimisation process (i.e. market dispatch engine process) • The DSO acts as a non-commercial Aggregator over a defined geographic area offering regional and national services to the central market. • The DSO procures, dispatches and settles DER from aggregators/retailers for D-network constraint management via the local market platform
Aggregator / Retailer	• The aggregator/retailer combines different DER and offer their aggregated output as flexibility services. The aggregator/retailer provides bids and offers directly to the local market platform. The aggregator/retailer activates the DER based on the dispatch instructions received from DSO via the local market platform

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Advantages	Disadvantages
• It allows DSOs to take full responsibility for management of DER in their own networks, facilitating a more decentralised and active operation and management of distribution networks • It allows for synergies between T- and D-network requirements to be identified through coordinated procurement processes, avoiding the risk of inefficiency through separate procurement of the same service from the same DER, or from different DER where that DER could have solved both issues. • It allows for the management of conflict between system service delivery requirements and distribution network capabilities as distribution network management issues can be explicitly accounted for in the procurement and dispatch processes through exchange of relevant information • It allows DSOs to prequalify, procure, dispatch and settle DER from aggregators/retailers for D-network constraint management • The DSOs have priority over the procurement and dispatch of DERs from the distribution network • A local market may create less barriers to entry for DERs	• DSOs do not have any existing experience with real-time dispatch processes, and have limited requirements for real-time management of their networks with respect to non-network assets. DSOs would need to establish this capability • A streamlined interface between DSOs and AEMO around the communication of aggregated bids in real-time will need be carefully designed to minimise complexity. This model may cause challenges in integrating a whole system dispatch optimisation with distribution network optimisation, since they will be separate processes operated by separate entities • It requires a seamless and coordinated dispatch process between DSOs and AEMO • DSOs may not be perceived as adequately independent and unbiased to fulfil this role. Models for managing any potential conflicts of interest with ring-fencing would have to be considered • DSOs will incur costs for the operation of a local market

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Market arrangements	• There is a central market comprised of wholesale and ancillary services markets (i.e. FCAS, NSCAS) for energy resources connected at the T-network that is organised and operated by AEMO • The central market collects bids and offers directly from T-network connected market participants and indirectly from D-network connected market participants via the IDSO (s), to facilitate AEMO's whole system optimisation process • There is a local market platform for DER that is facilitated by the IDSO(s). The local market platform collects bids and offers from DER via aggregators/retailers for T- and D-networks constraint management and electricity transmission system balancing • Both central and local markets facilitate the direct access of market participants to different markets enabling "value stacking" for energy resource owners
AEMO	• AEMO organises and operates the central market and is responsible for the dispatch and settlement of the market and system security and reliability across the five interconnected states through T- and D-network connected energy resources • AEMO procures energy resources connected to the T-network directly and to the D-network through the IDSO(s), optimising via the market dispatch engine • AEMO optimises dispatch across D-network boundary based on an aggregated dispatch schedule technically and commercially agreed with the IDSO(s) for every DER area
IDSO	• The IDSO organises and operates the local market for DER • The IDSO collects bids and offers for DER service provision from the local market platform. The IDSO converts DER bids into an aggregated bid stack per DER area and tests these against a dynamic operating envelope based on the network state in order to ensure the activation of these DER does not unduly constraint the distribution network. The IDSO passes the aggregated bids to AEMO for whole system optimisation • The IDSO allocates dispatch to individual aggregators/retailers based on the aggregated dispatch schedule across D-network boundary resultant from AEMO's whole system optimisation process (i.e. market dispatch engine process) • The IDSO acts as a non-commercial Aggregator over a defined geographic area offering regional and national services to the central market. • The IDSO procures and settles distributed flexibility resources from aggregators/retailers for D-network constraint management via the IDSO's local market platform
DNSP	• The DNSP is responsible for the development and operation of the distribution network following an active network management approach • The DNSP provides DER with static operating envelopes based upon the technical capability forecast of the D-network to accommodate DER dispatch in order to inform DER bids and offers into the local market • The DNSP exchanges information with the IDSO(s), such as network operational status and forecasts, to facilitate the consideration of distribution network constraints and the development of dynamic operating envelopes in the whole system dispatch process
Aggregator / Retailer	• The aggregator/retailer combines DER and offer their aggregated output as flexibility services. The aggregator/retailer provides bids and offers directly to the local market platform. The aggregator/retailer activates the DER based on the dispatch instructions received from IDSO via the local market platform

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Advantages	Disadvantages
• The IDSO(s) acts as an independent, neutral and transparent market facilitator removing concerns around conflicts of interest • It allows for synergies between T- and D-network requirements to be identified through coordinated procurement processes, avoiding the risk of inefficiency through separate procurement of the same service from the same DER, or from different DER, where that DER could have solved both issues. • It allows for the management of conflict between system service delivery requirements and distribution network capabilities as distribution network management issues can be explicitly accounted for in the procurement and dispatch processes through exchange of relevant information	• Seamless interfaces, between the IDSO and DNSP for exchanging real-time network status and distribution network constraints, and between the IDSO and AEMO for co-optimisation of resources in a multi-stage optimisation process, can be complex to achieve • New independent organisations would need to be established in each distribution network area to take on the role of IDSO • IDSO(s) would need to develop extensive capabilities on power networks and systems to deliver on their role and responsibilities

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Market arrangements	• There is a two-sided market platform, comprised of wholesale and ancillary services markets (i.e. FCAS, NSCAS) that is organised and operated by AEMO • The platform facilitates the direct access of market participants to the different markets enabling "value stacking" for energy resource owners • The platform collects bids and offers from market participants, including DER via aggregators/retailers, and makes them available to AEMO for whole system optimisation
AEMO	• AEMO organises and operates the central market and is responsible for the dispatch and settlement of the market and system security and reliability across the five interconnected states through T- and D-network connected energy resources • AEMO optimises the dispatch of energy resources considering T-network and D-network constraints • AEMO has a central role in coordinating how DER are used by the system as a whole including their procurement, dispatch and settlement for D-network constraint management • AEMO relays market bids from DER to the DSO, and the generated dynamic operating envelope from the DSO to DER • AEMO has the commercial relationship with DER via aggregators/retailers and is responsible for the financial settlement of market participants
DSO	• The DSO is responsible for the development and operation of the electricity distribution network following an active network management approach • The DSO provides DER with static operating envelopes based upon the technical capability forecast of the D-network to accommodate DER dispatch in order to inform DER bids and offers into the central market • The DSO assesses market bids, provided by AEMO, and D-network constraints in order to generate dynamic operating envelopes for DER, communicated through the market platform, which aim to respect distribution network constraints and inform their technical and commercial offering to the markets
Aggregator / Retailer	• The aggregator/retailer combines different DER and offer their aggregated output as system services. The aggregator/retailer provides bids and offers directly to the central market platform based upon their provided operating static and/or dynamic envelope. The aggregator/retailer activates DER based on dispatch instructions received from AEMO via the central market platform
Distributed Energy Resources	• Power generation technologies (including electric energy storage facilities) and end use electricity consumers (e.g. industrial and commercial) with the ability of flexing their generation or demand (i.e. demand side response) in response to control signals that are directly connected to the electricity distribution network. DER provide energy and network services to system operators (e.g. AEMO, DSOs, etc.) for electricity system balancing and network constraint management
Customer	• Domestic or industrial end-use electricity customers that are energy conscious and therefore have invested in off-the-shelf low carbon products (e.g. solar panels, heat pumps, electric vehicles, electric battery storage) to reduce energy bills. These customers may be exporting to and importing from the D-network and would seek to benefit from retailer's time of use tariffs; and/or • Domestic or smaller non-domestic end-use electricity customers with little or no interest in low carbon products or time of use tariffs

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Advantages	Disadvantages
• All market participants interact with a single entity (i.e. AEMO), via the two-sided platform, that acts as an independent, neutral and transparent market facilitator • Procurement, dispatch and settlement of DER for provision of system services is organised and operated by a single entity (i.e. AEMO) • DSO calculates the dynamic operating envelopes based on understanding and direct access to network operation data and constraints • Separation of market and network operation	• The expanded role for AEMO, requiring a wider range of resources, may have implications for AEMO's current funding model as it may need to be adapted • The DSO does not have direct control over the DER connected at the distribution network because they are procured and dispatched by AEMO • Seamless interface required between the DSO and AEMO for exchanging real-time network status and distribution network constraints and operating envelopes

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ALTERNATIVE USE CASE

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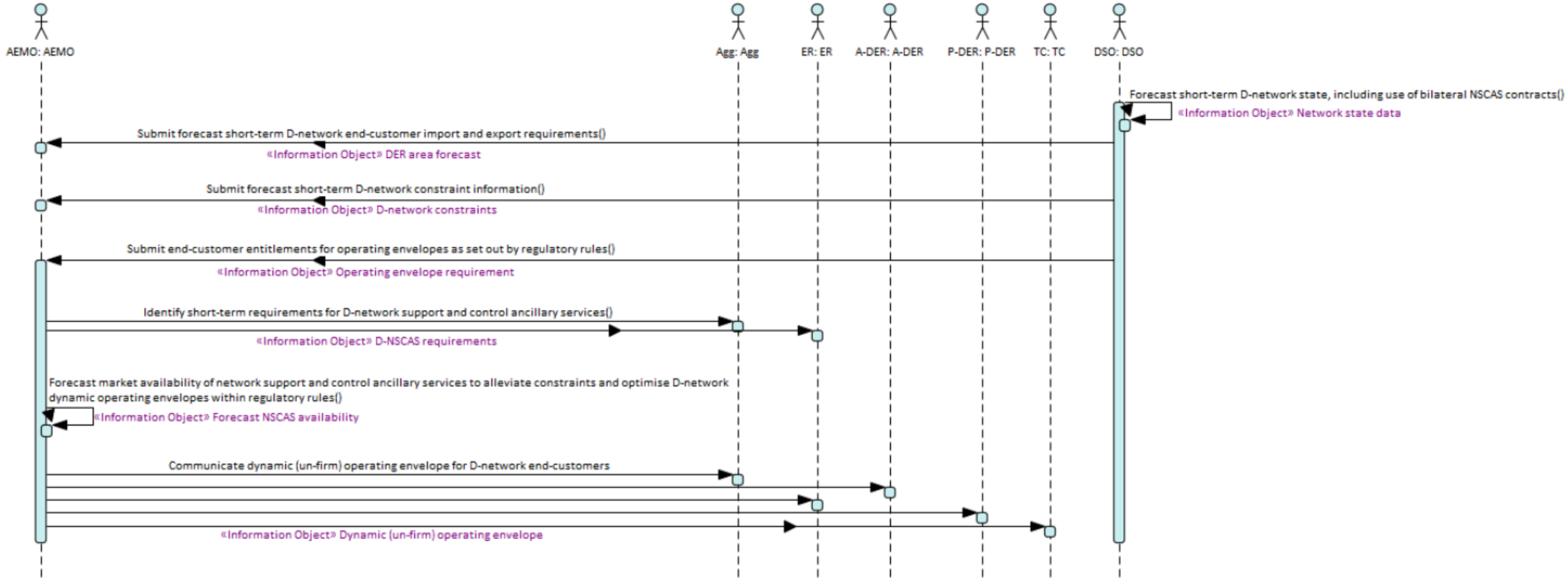
The use case:

– Function: 6. DER optimisation at the distribution network level

– Activity: 1. Optimise operating envelopes of distribution network end-customers

– Process: 3. Communicate operating envelopes to D-network end-customers (short-term, non-firm)



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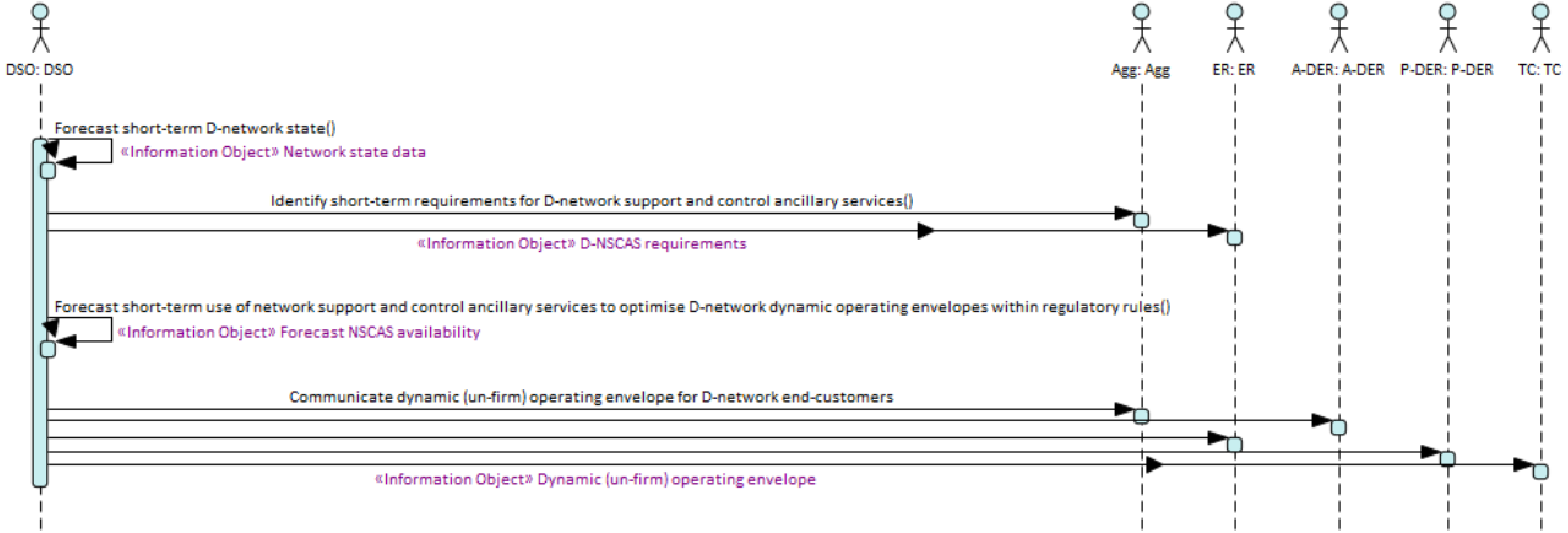
The use case:

– Function: 6. DER optimisation at the distribution network level

– Activity: 1. Optimise operating envelopes of distribution network end-customers

– Process: 3. Communicate operating envelopes to D-network end-customers (short-term, non-firm)



Fewer steps and one less actor compared to SIP model

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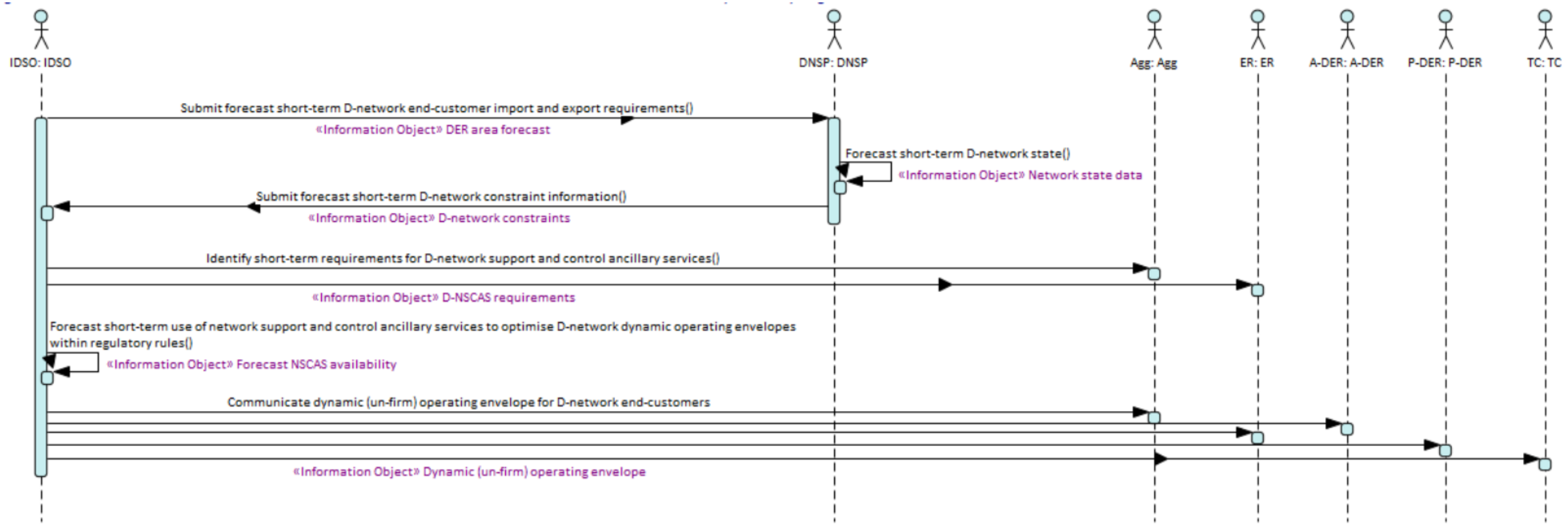
The use case:

– Function: 6. DER optimisation at the distribution network level

– Activity: 1. Optimise operating envelopes of distribution network end-customers

– Process: 3. Communicate operating envelopes to D-network end-customers (short-term, non-firm)



AEMO not involved (as in TST model) but two actors (DNSP and IDSO) to replace the DSO in the other models

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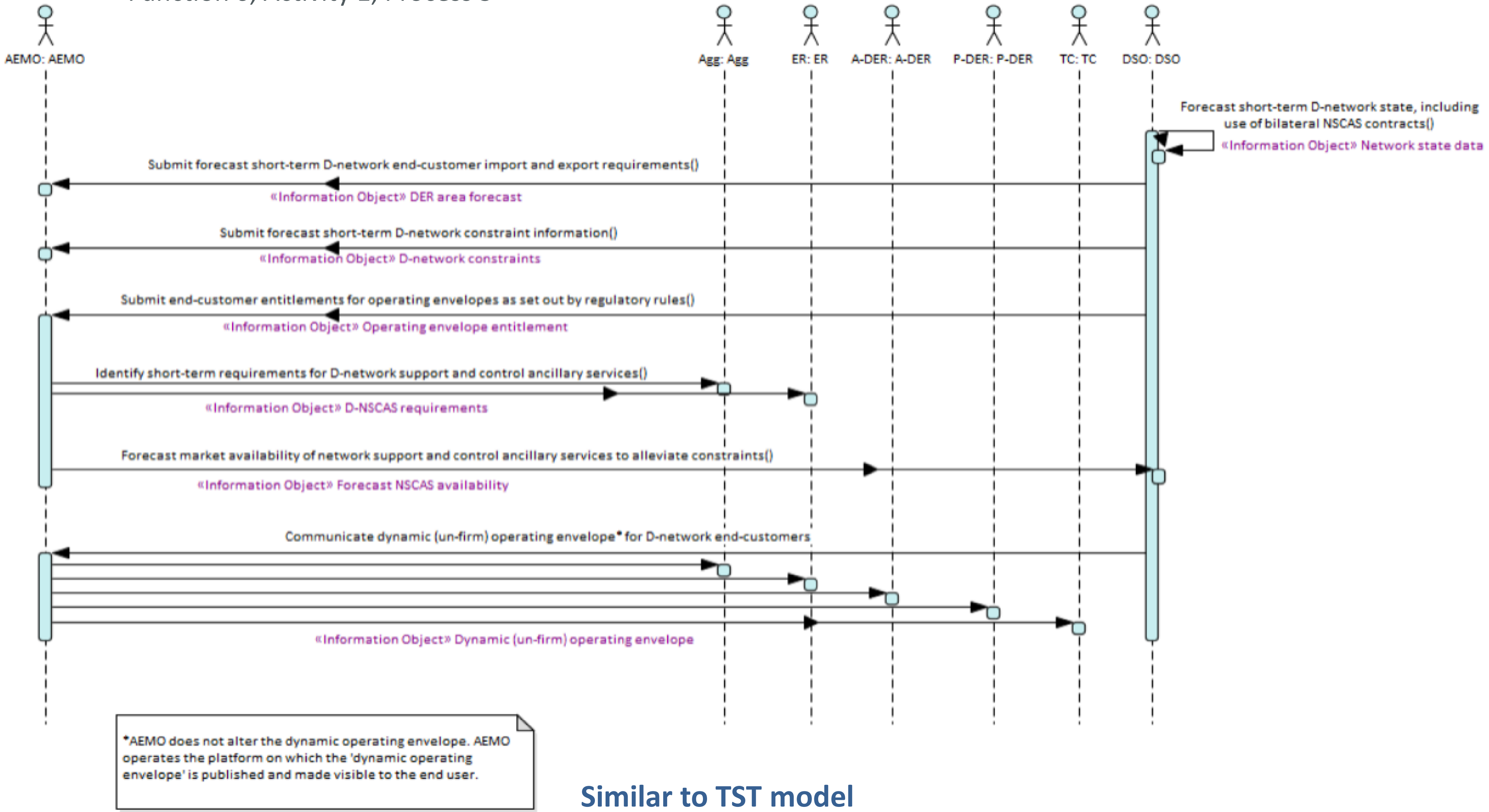
– Function 6, Activity 1, Process 3



Similar to TST model