Project EDGE

Public Interim Report

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This report has been developed with the support of:

Important notice

PURPOSE

The purpose of this document is to provide an update to the Australian Renewable Energy Agency (ARENA) and the industry regarding progress, preliminary findings, and lessons learned to date on Project Energy Demand and Generation Exchange (Project EDGE).

This publication has been prepared by AEMO using information available at 27 April 2022. Information made available after this date may have been included in this publication where practical.

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VERSION CONTROL

Version	Release date	Changes
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ARENA summary

Activity title	Project EDGE
Recipient	Australian Energy Market Operator Limited, in partnership with AusNet Electricity Services Mondo Power
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Executive summary

Project EDGE (Energy Demand and Generation Exchange) is an innovative, first of its kind, collaboration between the Australian Energy Market Operator (AEMO), AusNet Services (AusNet) and Mondo (collectively, the Project Partners), with financial support from the Australian Renewable Energy Agency (ARENA). Project EDGE seeks to understand, test, and demonstrate a proof-of-concept Distributed Energy Resources (DER) Marketplace that enables efficient and secure coordination of aggregated DER to provide wholesale and local network services within the constraints of the distribution network.

It also seeks to identify the approaches that can deliver long-term value to the national electricity system and all actors interacting with the DER Marketplace. The project's primary intent is to identify capabilities that can be replicated efficiently at scale across the National Electricity Market (NEM) and inform the development of a two-sided market that incentivises innovation and participation. The field trial will be conducted in an off-market environment, separate to AEMO's market systems to promote experimentation and avoid impacting live energy markets.

Project EDGE will generate an empirical evidence base that can inform the transition to a two-sided market that provides long-term value

Project EDGE will develop practical evidence demonstrating how AEMO can collaborate with industry to achieve the project objectives. The evidence base generated seeks to inform and guide technical, commercial and regulatory changes. Project EDGE will demonstrate three key function sets that are vital to the efficient and scalable integration of DER, and that will ultimately deliver value to customers.

- DER wholesale energy market integration.
  - Efficient wholesale integration could enable large-scale DER portfolios to participate in the wholesale market while remaining within the secure, technical limits of the distribution network and remaining visible to the market operator so it can efficiently coordinate the supply-demand balance.
- Scalable DER data exchange.
  - The wholesale integration and Local Services Exchange (LSE) function sets must be underpinned by scalable data exchange. An efficient DER Marketplace will need to enable the secure, efficient and scalable exchange of vast amounts of data between actors to facilitate the delivery of DER services. Project EDGE will test how a data exchange hub (also known as a messaging bus) can achieve this objective by enabling the DER Marketplace actors connected to the hub to share data with each other more easily than if they had to connect directly with each party.
  - One central hypothesis tested for the data exchange function is that a decentralised hub approach (with no broker, such as AEMO, in terms of hosting the hub or operating the hub to

transfer data) is the most efficient solution that could deliver the most net benefit to NEM customers. This approach involves public interest, shared digital infrastructure that mitigates the risk of single point of failure. Project EDGE will also test a centralised data hub (with a central broker such as AEMO operating the messaging bus and receiving and transferring data according to agreed rules).

- Local Service Exchange for network support services.
  - The LSE function could enable the efficient and scalable trade of local network services that Distribution Network Service Providers (DNSPs) procure from aggregators representing customers and their DER devices. This presents DNSPs with an opportunity to procure an alternative and more cost-effective solution to augmenting their distribution network and increase the efficiency of the system by maximising the value delivered from customer devices.
  - The nature of the cost recovery regulatory framework for distribution networks means that these alternative solutions (known as 'non-network' solutions in the energy industry) have the potential to provide price benefits to customers because of lower network management costs. LSE could also enable aggregators to stack value streams efficiently, be more competitive in energy markets, and provide better offers to customers. Ultimately, by participating in the DER Marketplace through aggregators, customers could maximise the value received from their DER devices while supporting the security and stability of the national electricity system, as their participation would enable more effective integration of DER into the grid.

The experience of the Project Partners will provide valuable insights and learnings for industry

Project EDGE is testing the roles and responsibilities of the three key actors in a DER Marketplace – the Market and System Operator, Distribution System Operators (DSO), and aggregators. The project seeks to demonstrate that these roles can be performed by expanding the functions and capabilities of existing actors in the current regulatory framework rather than creating new roles. In its capacity as the NEM Market and System Operator, with responsibility for the overall security of the power system and the central dispatch process, AEMO is best placed to take on the role of facilitating and coordinating the integration of DER into the wholesale electricity market.

Meanwhile, DNSPs are experts of their networks and it is appropriate they take on the responsibility of the DSO. This would include calculating and communicating the limits of their networks within which DER must operate when delivering services, and establishing/procuring local network support (or flexibility) services from DER.

Currently, aggregators orchestrate customer-owned DER devices to deliver energy services. Project EDGE is testing how a DER Marketplace can enable innovation by making it easier for aggregators to deliver multiple services to multiple parties simultaneously. Enabling simpler and more consistent participation allows aggregators to develop and offer compelling commercial propositions to customers, which in turn promotes greater participation.

These expanded functions of existing roles require the development of new capabilities. Project EDGE can provide the evidence to inform industry actors on the capabilities they will require to evolve into the new roles, and the technology and investment decisions that will enable them.

Preliminary lessons indicate Project EDGE may identify key issues that reflect conflicting preferences that will need to be solved by industry

Project EDGE will provide a robust evidence base to inform regulatory and business decisions. As a future DER Marketplace matures and evolves, there are likely to be key issues that may reflect conflicting preferences among marketplace actors on different approaches.

A key issue identified so far is the level at which dynamic operating envelopes (DOEs) are allocated. One approach – adopted by industry as the starting point principle for the roll out of DOEs – reflects the current customer-network connection framework. However, this approach may have implications on retail product innovation and customer choice. As such, an alternative approach may be preferred by aggregators. Project EDGE's research activities on DOE allocation seek to inform industry decisions on issues such as this.

Similarly, the aggregator role will be, foremost, as an agent for the end customer. Its role as an agent within the market – delivering device instructions on behalf of DNSPs and retailers – will be secondary and this will be a key consideration when there is conflict between the two agency roles (customer agent and market agent). There could also be conflicting preferences with respect to market and network prioritisation. It is assumed that aggregators, as market actors, will favour the market over network. However, network integrity and stability has always had priority over market operation in the NEM. This will require attention to be directed at how an over or under supply of local network services is managed and a need to resolve service prioritisation between local network services and the wholesale energy market. A challenge that Project EDGE will seek to inform is how to best co-optimise wholesale and local services and identifying the actor best suited to hold responsibility for this role and determining what services are prioritised. One approach to this co-optimisation challenge is to direct attention at service pricing to incentivise aggregators to prioritise local network services where required.

These, and other issues and different preferences, will need to be solved together by the broader industry with consideration for the long-term interest of all actors and consumers. Project EDGE will provide an evidence base to inform such industry decisions.

Structure of this report

This interim report summarises the key insights, challenges and learnings to date following comprehensive stakeholder engagement, the development of the Research Plan including research questions and hypotheses, and the EDGE Marketplace design process. Field tests and other research activities have not begun yet, therefore the insights in this report do not include evidence supporting or contradicting hypotheses. Future knowledge sharing reports will provide findings that demonstrate and recommend efficient and scalable approaches.

- **Chapter 1** provides an overview of the changing energy landscape because of the rapid uptake of renewable energy resources and DER, and the regulatory reforms underway that are being designed and implemented to address challenges and opportunities from this transformation. This chapter also outlines how the evidence generated by Project EDGE can support the design of these market reforms.
- **Chapter 2** provides a high-level summary of the project objectives, and the challenges and lessons learned from the detailed design process.

- **Chapter 3** outlines the roles and responsibilities being tested in Project EDGE and the key functions of the three Project Partners – AEMO, AusNet and Mondo – acting in the roles of the Market and System Operator, DSO and aggregator respectively.
- **Chapter 4** sets out the hypothesis for scalable data exchange that will be tested by the project, including key considerations, different approaches, and key challenges and lessons learned through the design and procurement process.
- **Chapters 5, 6, and 7** discuss the experience, preliminary findings, challenges, and lessons learned to date by each of the Project Partners in their respective roles as the core actors of the DER Marketplace. This includes a summary of their roles in the project, how they interact with the DER Marketplace, and the design and technology elements relevant to their functions in the project.
- **Chapter 8** summarises the purpose, approach and methodology adopted for the cost benefit analysis (CBA) and the target outcomes that it will assess.

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1 Introduction

Australia's energy landscape continues to experience a rapid transition as large-scale synchronous generation plants reach end of life, and the uptake and establishment of renewable energy resources and Distributed Energy Resources (DER) grows rapidly.

Residential rooftop solar photovoltaics (PV) now represents the largest generator in the National Electricity Market (NEM) and AEMO's 2021 Electricity Statement of Opportunities[1] (ESOO) indicates that a further 8.9 gigawatts (GW) of commercial and residential solar PV is expected to be installed by 2025 in the NEM, supplying up to 77% of total electricity demand at times by 2026.

The uptake of DER poses opportunities for customers and industry and assists decarbonisation as DER can deliver a range of electricity services that can optimise the value of consumers' investment in DER devices, and enable cost-efficient non-network solutions.

However, if DER are not effectively integrated into the electricity system, and unless the industry's operational toolkit evolves to be smarter and more dynamic, DER growth will create challenges for managing the power system, with minimum system load, limited visibility, and unpredictable DER behaviour all impacting the ability to maintain reliability and security of electricity supply.

AEMO, in collaboration with industry, is undertaking initiatives, trials and reform to support this shift in the energy landscape – away from a centralised, large-scale generation model to a model that also supports decentralised, small-scale and non-synchronous two-sided market participation.

1.1 Project EDGE will test a pragmatic approach to a two-sided market

In 2018, AEMO and Energy Networks Australia (ENA) commenced the Open Energy Networks Project[2] which sought to identify the most appropriate framework for building a two-sided marketplace[3].

The project identified the Hybrid model – where market operation functions are allocated to AEMO while Distribution Network Service Providers (DNSPs) optimise the distribution system operation – as the most appropriate framework for building a two-sided marketplace. However, the project also recognised there is no single definition of the Hybrid model, and it would need to be trialled to understand how best to implement it and maximise the efficiency and outcomes for customers and industry.

Project EDGE (Energy Demand and Generation Exchange) is intended to build on the outcomes of the Open Energy Networks Project, utilising the Hybrid framework as a guide for developing a trial to test and demonstrate how a two-sided marketplace might work, and inform current and future regulatory reform and market design.

[1] At https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-reliability/nem-electricity-statement-of-opportunities-esoo

[2] At https://www.aemo.com.au/initiatives/major-programs/nem-distributed-energy-resources-der-program/markets-and-framework/open-energy-networks-project

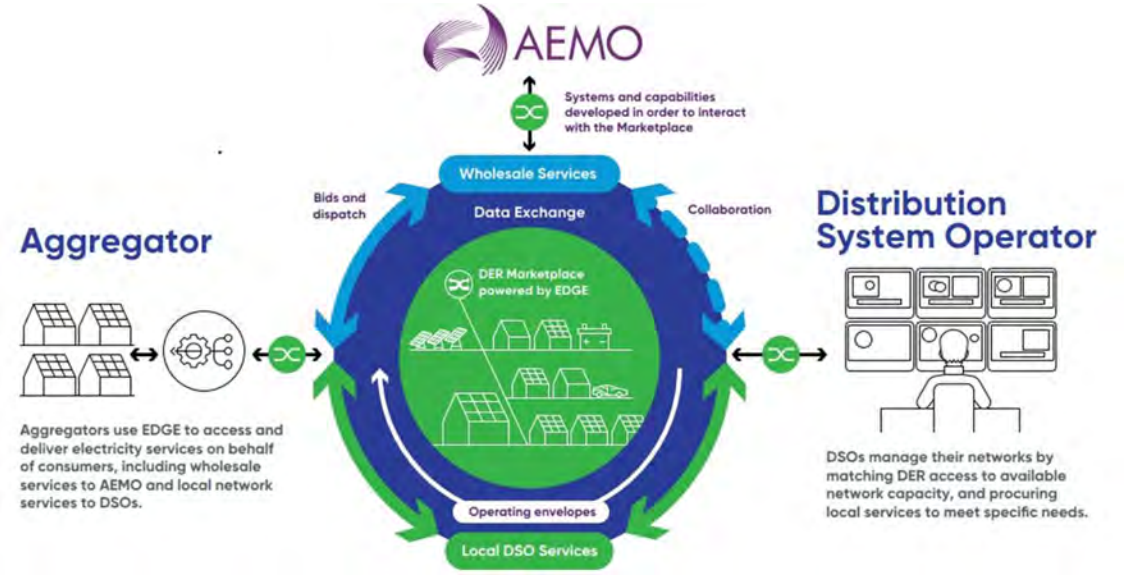
[3] At https://www.aemc.gov.au/news-centre/media-releases/what-next-two-sided-energy-market-implications-venturing-behind-meter

1.2 Project EDGE will demonstrate an efficient model to operationalise a DER Marketplace

The three Project Partners will collaborate to engage with stakeholders and test the vital functions of a conceptual framework called the DER Marketplace that supports efficient and scalable DER integration in the long-term interests of all consumers.

The **DER Marketplace** is not a single, AEMO-run platform or capability. Rather, it is an integrated digital ecosystem that links many systems and capabilities across various industry actors to enable the efficient and scalable exchange of data and services.

Figure 1 DER Marketplace conceptual view



While the DER Marketplace builds on the Hybrid model, the detailed design was underpinned by the National Electricity Objective (NEO)[4]. Project EDGE is taking a scientific approach to developing a robust evidence base that can be trusted by government, industry and the community. Key elements of this approach include the development of a Research Plan[5], a cost benefit analysis (CBA), and regular knowledge sharing and stakeholder engagement.

In developing the Research Plan, the design thinking framework followed a cascade approach underpinned by the NEO, to understand stakeholder expectations and challenges and develop project objectives, research questions and hypotheses to test the marketplace design options. The trial activities seek to solve the challenges to the electricity system presented by a high DER future and demonstrate whether the DER Marketplace represents the most efficient model to implement at scale across the NEM. The Research Plan will guide the delivery of the project and the generation of an empirical evidence base to inform the pathway to an efficient DER Marketplace. The design thinking framework applied is included in the Research Plan.

[4] The NEO is set out in the National Electricity Law, section 7, and is to promote efficient investment in, and efficient operation and use of, electricity services for the long-term interests of customers of electricity with respect to price, quality, safety and reliability and security of supply of electricity, and the reliability, safety and security of the national electricity system. See https://www.legislation.sa.gov.au/LZ/C/A/NATIONAL%20ELECTRICITY%20 (SOUTH%20 AUSTRALIA)%20ACT%201996.aspx

[5] At https://aemo.com.au/-/media/files/initiatives/der/2022/master-research-plan-edge.pdf?la=en

1.3 Evidence generated by Project EDGE is supporting market reforms

The evidence-based scientific approach adopted by Project EDGE will support recommendations that inform policy, regulatory and market decisions relating to reforms, roles and responsibilities, design, and the technology and processes needed by industry to operationalise a two-sided market. Figure 2 illustrates how Project EDGE is already informing, and will continue to inform, regulatory reforms and the development of industry capabilities, investment decisions and innovation.

The Energy Security Board's (ESB's) Post 2025 NEM redesign advice identified 'Integration of DER and Flexible Demand' as one of four key reform packages. The ESB has identified that the change in energy consumers' behaviour whereby more consumers are buying and producing their own power – the decentralised, multi-flow of electricity – provides a strong opportunity from DER and the energy transition to develop a two-sided market that could lower overall system costs for everyone, increase the efficiency of existing network assets, and optimise the utilisation of flexible loads and variable renewable energy[6]. The ESB recommends the reforms enabling a two-sided market are designed and implemented through the DER Implementation Plan, which takes a staged approach to establishing the regulatory, market and system structures required. Energy Ministers have accepted the ESB's advice to adopt the DER Implementation Plan to enable the reforms needed.

Project EDGE was identified as a vehicle to provide a robust evidence base to some of the changes recommended within the DER Implementation Plan, including Scheduled Lite, Flexible Trading Arrangements, and the roles and responsibilities of aggregators, retailers, DNSPs, and the market and system operator (AEMO). Learnings from the project through development, research and testing are already starting to test the approaches and influence the outcomes of such reforms and will continue to do so throughout and beyond the project.

Scheduled Lite

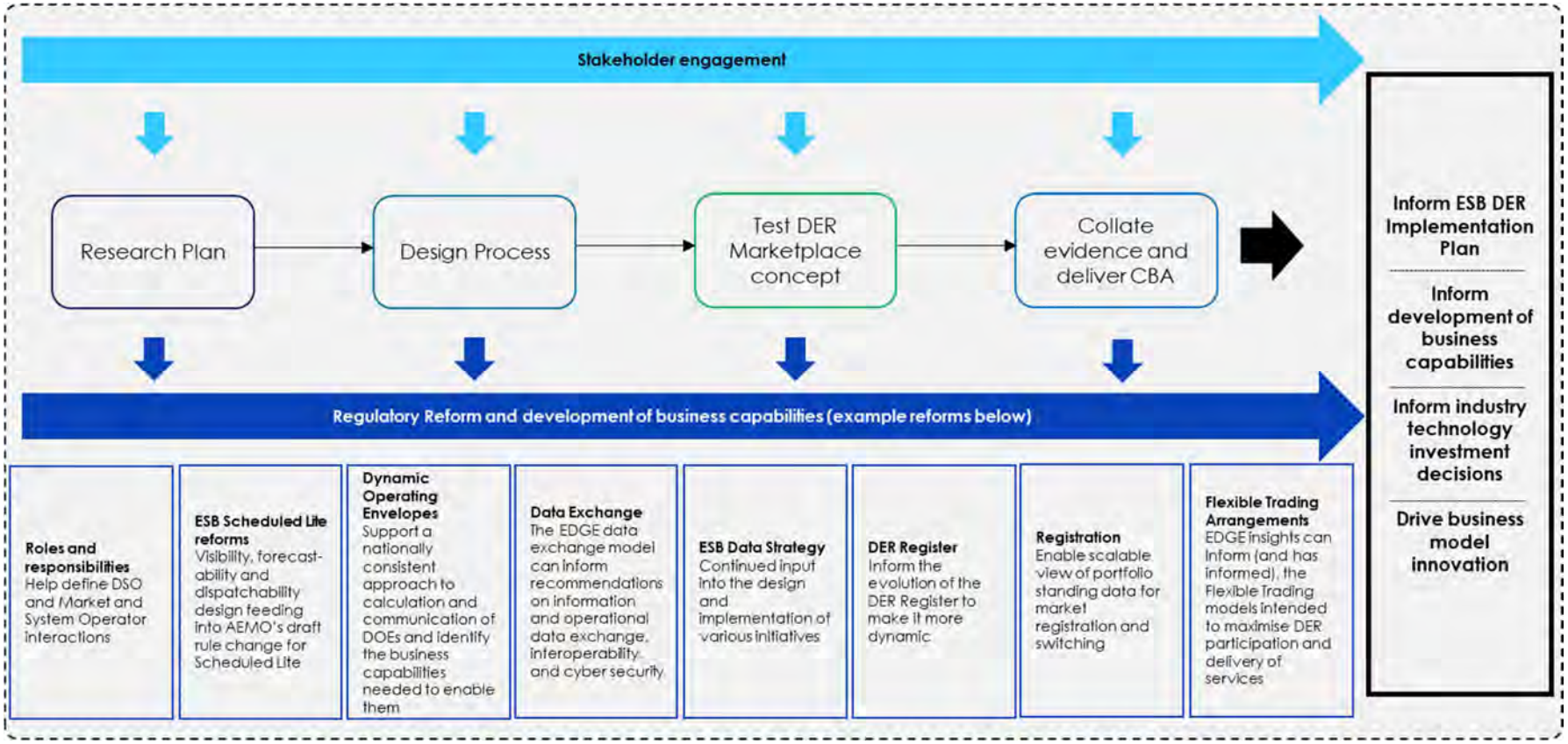
The ESB has recommended a mechanism – Scheduled Lite – to enable resources not currently scheduled in the market (including small generators and aggregated DER) to opt-in and either provide greater visibility to the market operator about market intentions, or to participate in dispatch with lighter telemetry obligations[7]. The reform seeks to encourage resources to opt-in through a combination of lower entry barriers and better incentives. The ultimate intent is to provide greater visibility of these resources to support increased market certainty through more accurate scheduling and enable AEMO to operate the market more efficiently and facilitate broader participation in dispatch.

The evidence base generated by Project EDGE can inform the detailed design of Scheduled Lite by demonstrating the level of visibility required that balances efficiency with optimised value to enable AEMO to improve the accuracy of operational forecasts and its ability to efficiently manage the supply demand balance.

[6] At https://esb-post2025-market-design.aemc.gov.au/32572/1629954551-esb-final-report-explainer-clean-and-smart-power-der-pathway.pdf

[7] At https://esb-post2025-market-design.aemc.gov.au/32572/1629945809-post-2025-market-design-final-advice-to-energy-ministers-part-b.pdf, page 87

Figure 2 Roadmap of key reforms and industry development that Project EDGE is informing and will inform in the future



Flexible Trading Arrangements

The reforms include the implementation of Flexible Trading Arrangements[8] to maximise the range of services that DER can provide and to give customers greater choice in accessing these services.

Two models have been proposed that are intended to separate controllable resources (such as solar PV and batteries) from uncontrollable resources and in doing so provide greater flexibility to customers to engage various, and specialised, energy services providers to meet their preferences and needs. Model 1 has progressed, and Model 2 will progress, through the Australian Energy Market Commission's (AEMC's) rule change process. Model 1 was considered as part of the Integrating Energy System Storage (IESS) rule change completed in December 2021. The operational and customer insights from Project EDGE relating to the integration and control of DER devices can inform the development of the Flexible Trading Arrangements Model 2 proposed by the ESB as its design goes through the rule change process. A rule change for Flexible Trading Arrangements Model 2 is currently under development.

IESS rule change

The IESS rule change[9] to consider integration of bi-directional units and move towards a two-sided market progressed in parallel to Project EDGE. This rule change considered Model 1 of the Flexible Trading Arrangements. The rule change enables 'Integrated Resource Providers' (IRPs) capable of two-way energy flow, including aggregators of small generation and storage units, to participate in the market with a single Dispatchable Unit ID (DUID) and a single bid to reflect the IRP's desire to charge or discharge for market prices. IRPs will receive a single dispatch target for their portfolio.

The consideration of bi-directional bids and offers being progressed through Project EDGE have contributed to AEMO's high-level design for implementing single DUIDs for wholesale IESS, and vice versa, with efforts being made to align the two projects. Project EDGE will also provide an opportunity to test the implementation approach (including, for example, validation of bid files) prior to the wider implementation of IESS.

[8] At https://esb-post2025-market-design.aemc.gov.au/final-advice-july-2021, page 85

[9] At https://www.aemc.gov.au/rule-changes/integrating-energy-storage-systems-nem

2 Project overview

Project EDGE is testing the concept of the DER Marketplace to address three key challenges – wholesale market integration, scalable data exchange, and Local Services Exchange (LSE). It is critical that these function sets provide long-term value to all end-consumers. Simplifying the participation and interaction experience of aggregators as marketplace actors will enable them to develop and offer simpler and more compelling value propositions to their customers that promote greater DER activation. The roles and responsibilities and interactions of the different actors, through these function sets, are discussed in Chapter 3.

2.1 Objectives

Underpinned by the NEO, 10 objectives were established at the outset of the project and were used to guide the development of a Research Plan and CBA approach. The Research Plan clearly outlines the design thinking and identifies the research questions and associated activities to test hypotheses that aim to solve the challenges posed by a high DER future. Details of the research questions, hypotheses and research activities can be found in the Research Plan[10].

2.2 Stakeholder collaboration

Engagement with stakeholders to date has provided valuable feedback on design elements, approaches, and impacts from DER integration into markets. These key insights are summarised in the Project EDGE Lessons Learned Report #1[11]. The project engagement plan with all stakeholders interested in or impacted by the outcomes of Project EDGE, including key engagement objectives, is included in the Research Plan[12].

2.3 Detailed design

The Project Partners encountered various challenges or identified lessons learned during the detailed design process for Project EDGE. This included lessons learned related to design of market functions, and challenges related to:

- Co-design process.
- Management and coordination of scope and solution vendors.
- Design methodology.
- Balancing business strategic roadmaps with the requirements of the project.

These lessons learned and challenges are explored in further detail below.

[10] At https://aemo.com.au/-/media/files/initiatives/der/2022/master-research-plan-edge.pdf?la=en

[11] At https://aemo.com.au/-/media/files/initiatives/der/2021/project-edge-lessons-learned-report-1.pdf?la=en

[12] At https://aemo.com.au/-/media/files/initiatives/der/2022/master-research-plan-edge.pdf?la=en

2.3.1 AEMO

The key lessons learned from AEMO's perspective were in relation to the co-design process (which also presented a challenge) and the design of market functions.

The co-design process

The detailed designing of new market functions in a collaborative way across three organisations with different core business focuses has proven to be a time-consuming process. Due to ambiguity in this novel work and the complex subject matter, the project teams experienced schedule delays early in the process as well as misinterpretation of discussions among Project Partners. The corrective structures implemented by the team and their benefits are described below:

- The project's use of the double diamond design methodology[13] sped up progress. This design process involves divergent thinking by exploring an issue broadly and in-depth, followed by convergent thinking by taking focused action. While the double diamond approach includes four key elements (discover, define, develop and deliver), it is not a linear process. Its use in Project EDGE's co-design process enabled the Project Partners to understand the spectrum of issues to facilitate the definition of problem statements and co-design from all relevant perspectives.
- The project's use of a 'services' roadmap laid the foundation for a common language understood by all participants in the co-design process and limited misinterpretation.
- The use of SIPOC (Suppliers, Inputs, Processes, Outputs, Customers) templates supported efficient structuring, identification and separation of key questions. SIPOC is a process management tool that facilitates the illustration of an end-to-end process as a means of developing new processes[14].

Design of market functions

- **Common communication protocols** – implementing a common communication protocol that allows communication among Distribution System Operators (DSO), aggregators and DER devices via a common data model with common commands has the potential to facilitate the scalability of dynamic operating envelope (DOE) data exchange in a DER Marketplace. Related work is underway through the ESB's consultation on Interoperability Policy[15].
  - One approach to enable the scalability of data exchange is applying the Common Smart Inverter Protocol Australia (CSIP-Aus) data schema to the communication of DOEs. This allows the 'chunking' of DOE updates to reduce the volume of data transmitted by setting a DOE 'duration' (e.g. three hours) as opposed to specifying a unique value for every 5-minute dispatch interval.
  - The sending of DOEs periodically instead of real-time is being tested, which would require a more powerful data exchange infrastructure.
  - Project EDGE is also trialling the application of materiality tolerances to DOE updates, e.g. DOEs that vary 0.1 kilowatts (kW) between dispatch intervals may not warrant an update to the aggregator.

[13] At https://www.designcouncil.org.uk/news-opinion/what-framework-innovation-design-councils-evolved-double-diamond

[14] At https://sipoc.info/

[15] At https://www.datocms-assets.com/32572/1639638298-esb-interoperability-policy-final-for-consultation-december-2021.pdf

- **Calculation of DOEs** – during high-level design, the project assumed the calculation of DOEs could be done in a way that economically optimised their capacity allocation among National Meter Identifiers (NMIs) based on comparing aggregators' bids. Through detailed design it was apparent that aggregator bids supplied at a whole-of-fleet-level (DUID) would not provide the granularity of information required for NMI-level DOE calculations.
  - Alternative models where aggregators supplied NMI-level bids were deemed costly for aggregators and therefore have scalability challenges so were not pursued.
  - Recognising that in theory DOE capacity could be economically optimised through either DNSP DOE calculations or independent market mechanisms, the project pivoted to attempt to answer the question 'what is the maximum theoretical value of economically optimising DOEs?'.
  - This will gauge whether this approach should be pursued, before exploring which model is best to do so.
  - This analysis will be conducted using a desktop study based on field trial data.
- The definition of bi-directional offers for energy submitted by an aggregator in the EDGE DER Marketplace for the total (net connection point position) price-responsive DER assets in their portfolio may not provide the market operator the necessary level of visibility. Project EDGE will compare two wholesale energy bi-directional offer definitions based on where the offered quantity of energy is measured:
  - Net Connection Point Flow (Net NMI) – measured at the connection point (NMI-level) and aggregated across the aggregator's portfolio, including both controllable and uncontrollable generation and load.
  - Flex Only – measured at a common measurement point behind the meter – representing the aggregation of all controllable DER assets at a site – and aggregated across the aggregator's portfolio. Flex Only ignores uncontrollable customer load and generation at a site.
- Flex bidding provides the market operator visibility of only the aggregated controllable price responsive DER assets in an aggregator's portfolio and is hypothesised to provide the aggregator with a simplified lower risk means of participating in wholesale energy dispatch.
  - Flex bidding encompasses all controllable loads and/or generation in an aggregator's portfolio and not individual devices.
  - This visibility is important as price-responsive DER is extremely difficult to forecast for AEMO compared with the aggregator who has data feeds directly from their customers' DER and understand their own price triggers.
  - Meanwhile, Net NMI represents the aggregated net position at a connection point including native loads.
  - As such, Net NMI is unlikely to provide clear visibility of the portion of the load pertaining to controllable DER devices[16].

[16] Lessons learned from AEMO's NEM Virtual Power Plant Demonstrations found that when live data is provided as net (net connection point flows), the information of activity behind the meter is lost. See https://aemo.com.au/-/media/files/initiatives/der/2021/vpp-demonstrations-knowledge-sharing-report-4.pdf?la=en, page 38

- A power system without visibility of high penetrations of price-responsive DER would lead to reduction in demand forecast accuracy, making managing operational risk to the power system (e.g. system security and blackouts) more difficult.
- For the aggregator, Flex bidding means they are accountable only for the assets under their control while Net NMI bidding exposes their service delivery and dispatch compliance to the risk of mis-forecasting the customer's uncontrolled load/generation at a site.
- Net NMI bidding is being contrasted with Flex bidding in Project EDGE to gain insight into the risk and operability in the market for aggregators where their bid, dispatch and telemetry quantity is different to DOE quantity adopted by industry as the starting point principle for the roll out of DOEs (Net NMI connection point)[17].
- To ensure alignment with current reform, Project EDGE worked closely with the AEMO IESS rule change team during the design of its 20 price band bi-directional bid file. As a result, some examples of how DER fleets can reflect bids in this new file format are available to aid industry learning and will be published in a separate document at a later date.

2.3.2 AusNet

AusNet's design process highlighted key challenges and lessons learned. This included:

- A fundamental design consideration was the need to establish definitions and design of local services based on network conditions. It is important that local services facilitate integration of DER and reduce cost for customers through non-network solutions that support more cost-effective network planning and management. This requires consideration of the local network services a DNSP could procure, and timeframes (e.g. ahead of time or following a loss of supply) to meet a particular network objective in certain network conditions (e.g. preventing the network from exceeding its firm capacity, rectifying a network abnormality, or managing voltage). An open challenge that has yet to be resolved is determining how to measure and validate performance of delivery of services. Preliminary findings and lessons learned to date are discussed in Section 6.2.4.
- The distribution network industry raised concerns about potential risks in providing aggregators with functions traditionally associated as network responsibility, e.g. being responsible for elements of compliance with operating limits because it is hypothesised that aggregators will favour the market over the network. As such, the risk is that network integrity and stability may not be prioritised.
- Accordingly, the distribution network industry expressed the need for a fail-safe mechanism for active DER operation and a means to manage performance compliance as critical requirements of the design.

2.3.3 Mondo

The key challenges experienced and lessons learned by Mondo through the detailed design process were:

- Achieving standardisation of information exchange where standards are developed ad hoc rather than through a structured and planned timeframe with appropriate lead-time.

[17] The Distributed Energy Integration Program (DEIP) Dynamic Operating Envelopes working group agreed on the principle that DOEs can be initially allocated at the connection point to the network (regardless of the number or configuration of devices behind the connection point) as a first step in DOE roll out. At https://arena.gov.au/assets/2022/03/dynamic-operating-envelope-working-group-outcomes-report.pdf, p.15

- Managing the scope to achieve the simplest, fit-for-purpose design options that meet trial requirements while they may not necessarily be suited to scaled production implementation.
- Managing and coordinating several solution vendors in the development of a common platform operating arrangement.
- Balancing Mondo's strategic platform roadmap with the requirements of Project EDGE.
- Applying the most appropriate design methodology, e.g. the application of a multi-organisational agile development methodology for activities such as interface definitions which may be better suited to a waterfall type implementation.

3 Defining roles and responsibilities

The Open Energy Networks Hybrid model provides a guide on the roles and responsibilities of the Market and System Operator, the DSO and aggregator. Project EDGE looks to test these roles in line with this model, rather than creating new roles. These roles are:

- AEMO – in its capacity as NEM Market and System Operator.
  - Under the National Electricity Rules (NER), AEMO has overarching responsibility for security of the power system, including the distribution system. AEMO is also responsible for establishing the central dispatch process and ensuring that network limits (including transmission and distribution limits) are considered in that process. The NER also give AEMO the power to delegate its system security functions to NSPs[18]. As DNSPs are experts of their networks, it is appropriate that they are responsible for calculating and communicating the limits of their distribution networks to give AEMO confidence all network limits are appropriately considered.
  - As the technical characteristics of the grid become more complex and the importance of DER increases, the capabilities to effectively manage the distribution network and the scope of the DSO needs to grow.
- DSO – the same DNSP role, enhanced with new business capabilities.
  - DNSPs must build new capabilities, for instance to create DOEs that inform the limits in which DER must remain while delivering wholesale and/or local network support services. The project explores how DNSPs could procure network support services from DER aggregators in an LSE that facilitates structured bilateral procurement.
- Aggregator – responsible for the aggregation of customer-owned DER and delivery of services.
  - The aggregator role remains largely the same, which is to orchestrate customer-owned assets to deliver energy services. Project EDGE aims to enable innovation by making it easier for aggregators to deliver multiple services (wholesale and local) to multiple parties, and easier to exchange necessary data in doing so. If aggregators have a simpler and more consistent user experience when delivering multiple services, it is easier for them to create simple and compelling commercial offers to their customers.

[18] At https://energy-rules.aemc.gov.au/ner/372/79839. NER clause 3.8.1 provides that AEMO must operate a central dispatch process for certain units, loads, and services to balance power system supply and demand and maintain power system security. Meanwhile, clause 3.8.10 provides that AEMO must determine any constraints on the dispatch of certain units, loads, and services in accordance with its power system security responsibilities under NER Chapter 4. These responsibilities include ensuring interactions with Distribution System Operators (as defined in the NER) for both transmission and distribution networks so that power system security is not jeopardised by operations on the connected transmission and distribution networks (clause 4.3.1(w)).

3.1 Interaction of the roles in the DER Marketplace

Project EDGE is testing the interactions of AEMO, aggregators and DNSPs for wholesale market integration, and the interactions between DNSPs and aggregators for local service exchange.

Figure 3 outlines the functions of each of the roles being developed by Project EDGE and how the roles interact and work together. As the project progresses, further insights and learnings on the roles, responsibilities and functions of each participant will be made available.

3.1.1 AEMO as the Market and System Operator

AEMO's primary function in the role of the Market and System Operator is market optimisation and keeping the power system secure. In the context of Project EDGE this includes the wholesale bids, dispatch, settlements, administrative and coordination function outlined in the purple box in Figure 3. AEMO's primary interaction through these functions is with the wholesale market integration element of the DER Marketplace, which is represented by the light blue process arrows. Specifically, enrolling aggregators, subscribing to operational data, and running wholesale dispatch with instructions sent to aggregators to fulfill using their fleet of DER.

The project aims to assess the feasibility of aggregated DER operating as a scheduled resource and testing the most efficient and appropriate design options of a yet-to-be-defined form of scheduling 'lite' (as recommended by the ESB). The AEMC rule change process will consult on the specific design of the Scheduled Lite models. Project EDGE will be able to inform this design and consultation process by testing simple options for obtaining visibility and dispatch of DER fleets.

AEMO will also interact with DNSPs to consider distribution network limits in the wholesale dispatch process. DNSPs are the experts of the distribution network and will be responsible for calculating distribution network limits and communicating them to AEMO and aggregators. However, there is a spectrum of approaches to incorporating these network limits into the wholesale dispatch process that are being investigated in Project EDGE

AEMO's interaction with LSE, represented by the green process arrows, is the role of facilitating the data exchange for the trade of services, reporting and analytics. AEMO is not directly involved in the bilateral trade of local services between the DSO and aggregator.

3.1.2 AusNet as the DSO

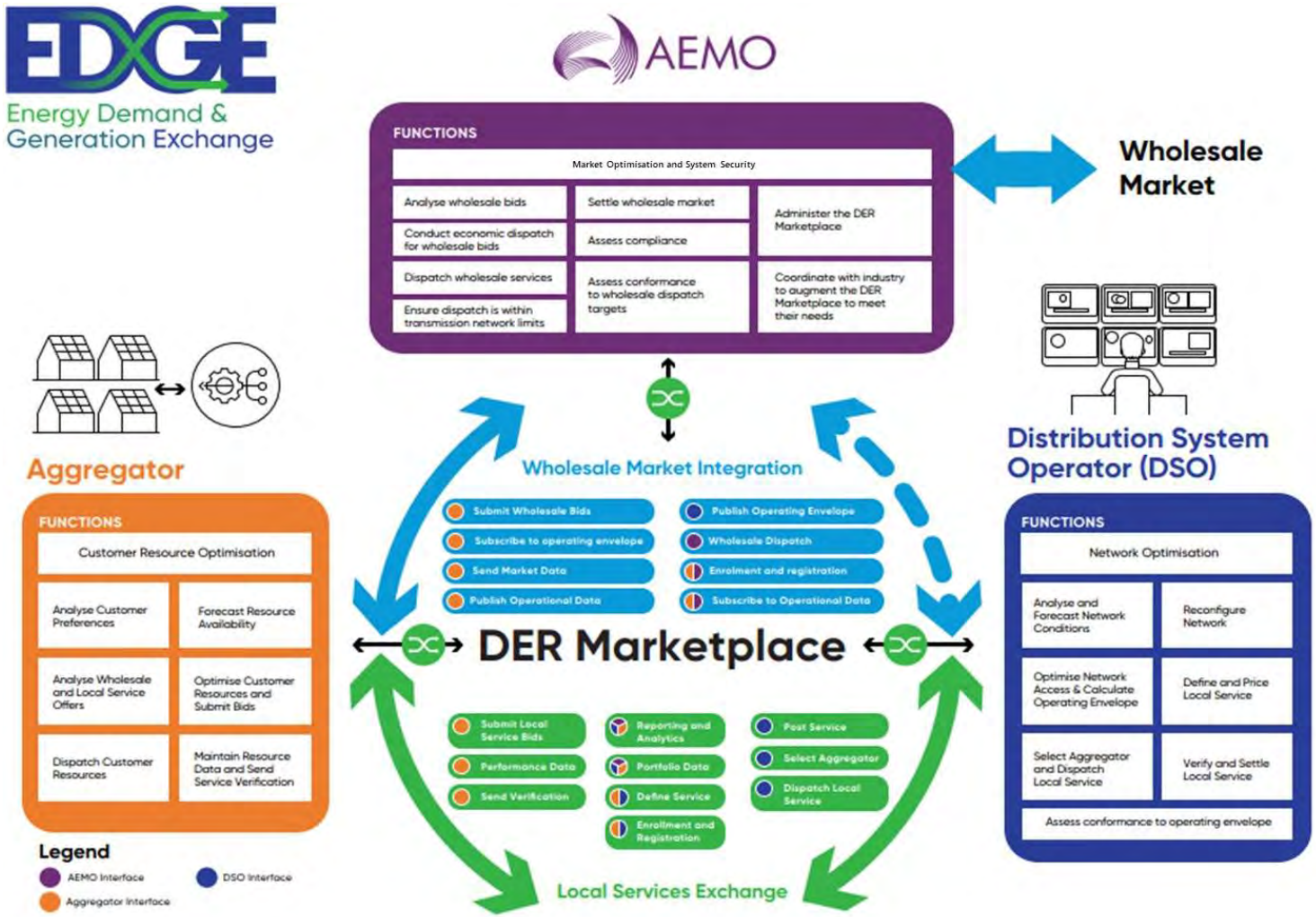
AusNet is the sole DNSP involved in Project EDGE where its role is to act as the DSO with the primary function of network optimisation. The ancillary functions enabling its core objective are outlined in the navy blue box in Figure 3 and include analysing and forecasting network conditions, optimising network access and calculating DOEs and defining and pricing local services based on identified network needs.

In Project EDGE, the DSO supports aggregator participation in the wholesale market by determining and providing the distribution network limits (via NMI level DOEs) within which bids can be constructed. These DOEs are also based on agreed objective functions and priorities to optimise DER-to-network participation, while managing local distribution network security, reliability and asset risks.

In the LSE, the DSO interacts with aggregators by publishing service requirements, selecting aggregators, and dispatching the procured local service. In Project EDGE, AusNet's role also includes defining, designing and operationally trialling the trade of local network services between AusNet and the aggregators participating in Project EDGE via the DER Marketplace. These local services use

network connected DER to enable improved reliability and quality of network supply to customers via the alleviation of operational constraints.

Figure 3 DER Marketplace functions delivered by AEMO, DSO and aggregator roles



3.1.3 Mondo as the aggregator

Although Project EDGE anticipates testing the operation of the DER Marketplace with multiple aggregators, Mondo is the sole aggregator for the first three trial phases of the project and the main actor to drive the project's Customer Insights Study. Mondo's primary role as an aggregator in Project EDGE is customer resource optimisation. This includes analysing wholesale and local service offers within its DER portfolio. Aggregators' assessment of market opportunities will have several considerations:

- The preferences of the customers they represent.
- Understanding and forecasting the resource capacity and availability of their DER portfolio.
- Analysing wholesale and local service offers and understanding network limits.
- Optimising and submitting bids that share revenue among all parties by providing a stacked delivery of wholesale energy and local network services simultaneously.
- Dispatching customer resources in compliance with instructions and network limits when delivering local services.

The aggregator as the customer representative has the most interactive role, participating in both wholesale and local services in the DER Marketplace. Its functions and interactions are outlined in Figure 3, where orange represents the aggregator. To enable its functions, Mondo will need to acquire customers and manage a portfolio of customer DER, and develop incentives and business models for optimising the value stack for all parties (customers, Mondo, and AusNet).

3.2 The development of the roles and responsibilities aligns with the Energy Security Board's DER Implementation Plan

The ESB has identified that the roles and responsibilities of AEMO, DNSPs, aggregators and retailers, and customers, need to evolve to meet future needs and has outlined directions on the expansion of existing functions. The ESB DER Implementation Plan integrates the evolving roles and responsibilities of existing actors in the package of reforms and one of the initial measures is the definition and implementation of these changed roles. The changes must enable opportunities and provide safeguard for customers, facilitate innovation by service providers, enable AEMO and DNSPs to maintain a secure and reliable energy system, and facilitate an efficient market that delivers value to all customers[19].

Project EDGE will test many of these proposed new responsibilities, such as market registration, responsibilities relating to DOEs, DER energy services procurement, data exchange, and interaction among different actors. Project EDGE's trial activities can demonstrate how the evolved roles and responsibilities can deliver the intended objectives and inform the design of the necessary regulatory and market changes.

3.3 Lessons learned

Project Partners experienced a variety of challenges from which key lessons were learned through the process of designing the roles and responsibilities for Project EDGE.

[19] At https://esb-post2025-market-design.aemc.gov.au/32572/1629945809-post-2025-market-design-final-advice-to-energy-ministers-part-b.pdf, p. 66-67

3.3.1 AEMO

- A challenge faced by Project EDGE in the design of roles and responsibilities was identifying how to best co-optimise wholesale and local services. This includes identifying the party best suited to hold responsibility for this role and determining what services are prioritised. A key hypothesis being explored is that aggregators will be guided by economic outcomes for customers, specifically that the aggregator should be responsible for ensuring DER can effectively provide stacked delivery of wholesale and local network services simultaneously instead of the market operator co-optimising these services. If the hypothesis is supported by research, it would represent a comparatively simple mechanism for co-optimising wholesale and local services compared with a framework prescribed through regulatory rule and system changes that establish preference for one type of service over another.
- This hypothesis means that when making bi-directional offers, aggregators will need to ensure committed capacity at a local level is reflected in the price band that will be cleared in the wholesale market (e.g. the price floor). In the Project EDGE DER Marketplace, aggregators can submit bi-directional offers (an offer that includes both generation and load) as price/quantity pairs that contain 20 price bands. Price bands are fixed for the following trading day, per current wholesale market rules. Aggregators have flexibility to adjust the capacity offered in each price band for the trading day but cannot update the price in the price bands. This means that the DSO's role would be to confirm the local services required, while the aggregator's role as part of its function to dispatch local services would include co-optimisation and stacking with wholesale energy services.
- There are industry concerns regarding a 'one platform' approach to data exchange (explored in detail in Chapter 4). The project's hypothesis is that the systems and capabilities of all actors in the DER Marketplace should work together and this can be facilitated most efficiently through a data exchange hub. Through a detailed design process, Project EDGE is investigating how the digital infrastructure could be shared by the industry if this option is best aligned with the NEO.

3.3.2 DSO

- DNSPs will need to develop capabilities and processes for determining the value of local services, and measuring and providing local services provided by DER. This includes identifying appropriate measurement techniques and methodologies in the context of DER participation in wholesale energy market activities that impact local network voltages.
- To establish the electrical network models (including full topology and impedance models), DNSPs will need accurate network data. Preliminary learnings from off-line testing of University of Melbourne's (UoM's) DOE algorithm suggest it can reliably calculate available access to the network by DER at the specific site connections if an accurate set of network and customer data is input. This suggest that DNSPs will require data collection and validation capabilities and identification of innovative approaches for data validation.
- To facilitate application of an algorithm across an electricity distribution network, in addition to accurate electrical network and complete customer data, DNSPs will also need computation capabilities. The computational capabilities required will depend on the DOE calculation approach adopted, which is likely to be informed by the proportion of active DER customer connections in the electricity network.

3.3.3 Aggregator

- The aggregation role must consider the fact the aggregator remains foremost an agent for the end customer. Its role as an agent within the market is secondary, and where there is a conflict between these two agency roles, a resolution is required in line with customer preferences.
- Industry will need to identify an appropriate balance between information requirements and the costs associated with such requirements.
  - Aggregators should be required to provide information to perform their role and participate in a manner that maintains power system and market security.
  - However, information obligations for aggregators and the associated costs need to be sufficiently assessed and assigned in ways that do not create entry barriers for this nascent market.

4 Scalable data exchange

For the last century the power system has maintained a centralised and highly specialised model for power system data exchange, characterised by relatively few large assets, controlled by relatively few entities, sharing data among AEMO, transmission network service providers (TNSPs), DNSPs and retailers. Key categories of power system data include real-time operational data and network limit and constraint data.

Operational data

Operational data is used to monitor the performance of large generating plants and network assets and is shared using a dedicated Supervisory Control and Data Acquisition (SCADA) system.

Assets too small to register in the wholesale market (less than 5 megawatts [MW]) have been largely exempt from onerous data sharing obligations. Assets large enough to register and be scheduled in the wholesale market have been able to afford the high costs of connecting to, and sharing data via, the SCADA system. These costs for connecting a scheduled plant to the SCADA system are estimated to be between $700,000 for a basic connection and $2.5 million for an advanced connection[20].

Network limit and constraint data

In the past, only transmission network constraints have been considered in the central dispatch process for the wholesale market, as DER was not at material levels that could cause electricity flows to breach distribution network limits. TNSPs work with AEMO to share network limit information and develop constraint equations that are used in the central dispatch process. These constraints ensure generators are collectively dispatched so that electricity flows on the transmission network remain within secure limits.

Although the NEM transmission network spans most of Eastern Australia, the relevant transmission network limit and constraint data can be viewed and shared in relatively simple systems, for example in AEMO's NEM single line diagrams[21].

4.1 Scalable data exchange in a decentralised power system

As shown in Figure 4, AEMO's draft 2022 Integrated System Plan's (ISP's) most likely scenario (Step Change scenario projects NEM capacity in 2050 to be over 280 GW, of which 114 GW (40%) would be connected to the distribution network[22].

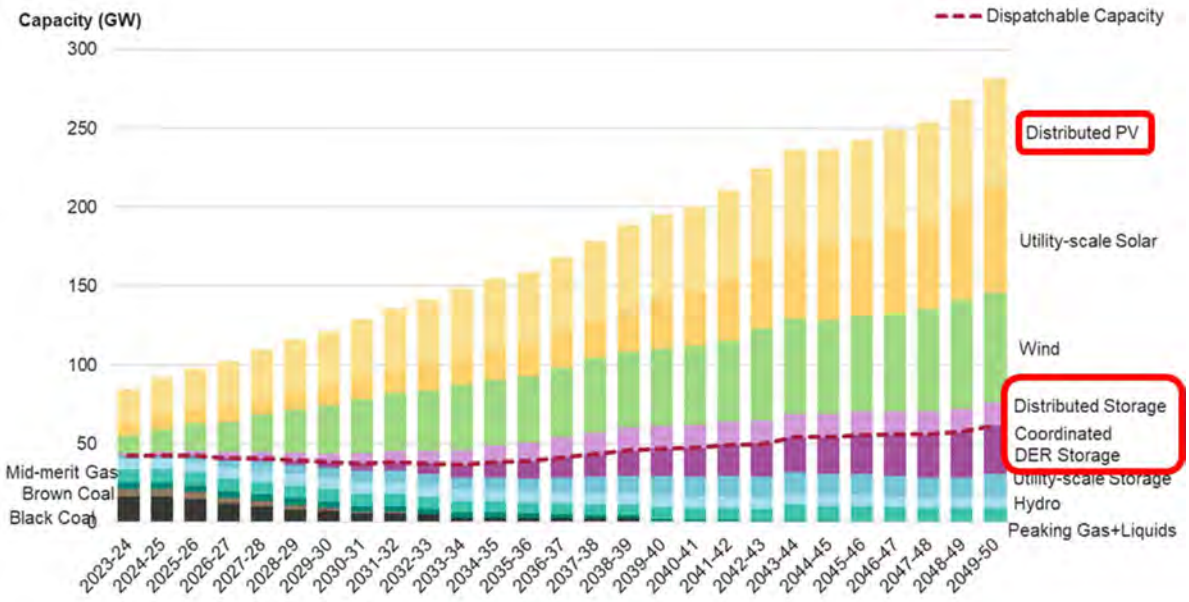
Under the Step Change scenario, there could be times when the entire NEM demand for electricity may be met with distribution-connected resources. To facilitate a secure and reliable power system in that future, there will need to be orders of magnitude more data being shared among many more industry participants relating to millions of generating and storage (e.g. batteries) units.

[20] At https://www.aemc.gov.au/sites/default/files/documents/ghd_report_-_assessment_of_scheduling_costs_-_final.pdf

[21] At https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/diagrams-and-previous-maps

[22] At https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp

Figure 4 Forecast NEM capacity by resource type to 2050, draft 2022 ISP Step Change scenario



In relation to the key categories of data outlined above:

- **Operational data** – scalable, reliable, secure and affordable systems will be required to transfer data from millions of distribution-connected devices into operational control systems, most likely at varying levels of aggregation. To ensure affordability, alternatives to SCADA systems will need to be explored. While these systems are critical to the operation of the NEM's current scheduling framework because of the granularity of data they communicate with the market operator's control rooms, they are a significant entry barrier for new, smaller participants into central dispatch in terms of affordability. However, anything less robust than a dedicated SCADA feed is inherently less reliable in providing the visibility the system operator needs to support and manage system security. Project EDGE is testing the use of public internet as a more affordable alternative for DER aggregators to provide visibility of resources and participate in the market, while enabling the system operator to undertake its system security functions.
- **Network limit and constraint data** – distribution networks are much more expansive and complex than transmission networks; there is over 45,000 km of transmission grid but over 850,000 km of distribution grid in Australia[23]. In future, distribution network limits will need to be considered in the operational timeframe, with DNSPs sending limits to DER operators (such as aggregators) to ensure that millions of distributed devices collectively operate within secure network limits. This is a fundamentally different process to how transmission network limits are currently adhered to, but these new DNSP capabilities will be a foundational building block of a secure power system in future.

Scalable data exchange is, therefore, at the core of the DER Marketplace concept and is one of the key functions being examined in Project EDGE. The design principles applied when considering how

[23] At https://www.cleanenergycouncil.org.au/resources/technologies/grid

to achieve scalable data exchange in a decentralised future can be found in the Project EDGE Research Plan[24].

Project EDGE tests how a data exchange hub can achieve efficient and scalable data exchange whereby those connected to the hub can share data with each other more easily than if they had to connect directly with each party. Importantly, this applies only to interactions between aggregators/customer agents, DNSPs and AEMO – it does not apply to how aggregators/customer agents choose to communicate and exchange data with customer devices under their control[25].

The conceptual view of the DER Marketplace is illustrated in Figure 5 below, with the navy blue ring representing the data exchange hub. The DSO can share DOEs with multiple aggregators via a single integration with the DER Marketplace; equally each aggregator could receive DOEs from multiple DSOs via their single integration with the DER Marketplace.

Figure 5 DER Marketplace as a data exchange hub

4.2 Theoretical efficiencies of different approaches to data exchange

There is a spectrum of theoretical approaches to exchange data among many parties, including:

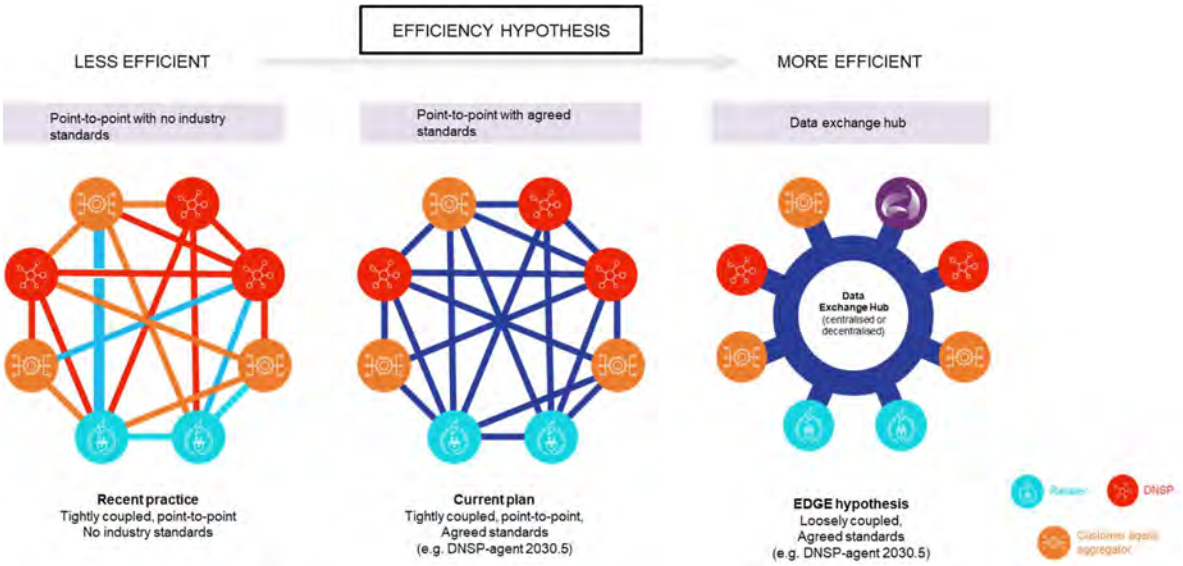
- Point-to-point with no industry standards – parties make point-to-point connection with each other to share data using their preferred communication methods/protocols.
- Point-to-point with agreed standards – parties make point-to-point connections with each other but agree standard communication processes and terminology between all the parties.
- Data exchange hub – establish an industry-wide data exchange hub, so that any party connected to the hub can easily share data with anyone else connected to it. The data exchange hub concept can be achieved in either a centralised or decentralised way.

[24] At https://aemo.com.au/-/media/files/initiatives/der/2022/master-research-plan-edge.pdf?la=en

[25] The interoperability of devices is considered in the ESB's Interoperability Policy for Consultation, Stage 1: inverter-based resources. See https://esb-post2025-market-design.aemc.gov.au/reports-and-documents#technical-working-groups

Each of these approaches is described further below. Project EDGE is testing the hypothesis that a data exchange hub, and specifically a decentralised data hub (DDHub), will deliver the highest net benefit to NEM customers in the most likely Step Change scenario from the Draft 2022 ISP. The calculation of net benefits will take place in an independent CBA to be delivered by Deloitte. The hypothesis of the spectrum of efficiency is illustrated in Figure 6.

Figure 6 The hypothesis of the spectrum of efficiency for different approaches to data exchange



4.2.1 Point-to-point data exchange with no industry standards

While this is suitable for small-scale data exchange, it becomes complex and inefficient when multiple parties exchange various data streams. Barriers to participation may also arise based on the communication protocol(s) selected for the integration, where original equipment manufacturers (OEMs)/aggregators operating in global markets may not be set up with the required protocols in the Australian market.

4.2.2 Point-to-point data exchange with agreed standards

This is the current pathway for DNSPs sending DOEs to aggregators/customer agents. Each DNSP could develop its own server (DER comms hub) aligning to the 2030.5 Common Smart Inverter Profile for Australia[26] and all customer agents register with each DNSP's server. This is a more efficient approach than point-to-point data exchange without the agreed standard, but it requires every customer agent to register with each DNSP. Although this could be a relatively simple process, there may still be small differences (including data models, software and hardware architectures, and integration methods) in how each DNSP applies the standard that adds complexity for customer agents operating across multiple DNSP regions. These small differences in implementations over time can proliferate integration requirements and negate efficiency gains. In addition, this does not reduce the number of integrations that customer agents will need to maintain, particularly as active DER scale. This creates additional cost to industry that could be passed onto the aggregator's customers and may also create entry barriers as a result of technical and cost burden.

[26] At https://arena.gov.au/knowledge-innovation/distributed-energy-integration-program/interoperability-steering-committee/

Moreover, and independent of how any standard might be applied across DNSPs, the point-to-point data exchange approach is not designed to facilitate any single DER operating across two or more DNSPs within a short period of time (e.g. over the course of a few hours or a day). For example, DNSPs might need to share and align DER identities and capabilities across their networks with other DNSPs to coordinate services from a specific electric vehicle (EV) that might be travelling across a region serviced by more than a single network.

There is a further use case that adds complexity to the point-to-point approach. Retailers whose residential customer base has a high proportion of rooftop solar could see their portfolio net exporting to the system when prices are negative. As retailers are exposed to negative prices, they would have to pay for their customers to export to the grid. If prices are at the market floor (-$1,000 per megawatt hour [MWh]), retailers would effectively pay $1 for every kilowatt hour (kWh) their customers export to the grid, which could add up quickly. On top of this, retailers also pay feed-in-tariffs to customers for exports that could be up to 16 cents per kWh.

Retailers are incentivised to reward customers for increasing their demand to soak up solar energy and not export it to the grid. These rewards may include offering customers cheaper or free energy on Spring weekend lunchtimes, or incentives for actively managing their rooftop solar exports. Retailers may incentivise (pay) customers who allow signals to be sent to their devices that reduce exports to the grid when spot prices fall below a negative price threshold.

One thing stopping these programs being more common is the lack of efficient systems for retailers to send such signals to the many different brands of inverters at customer premises. Inverter manufacturers can send real-time signals over the internet to their branded devices. However, there are over 100 different OEMs, with over 1,400 different products, on the Clean Energy Council's approved inverter list[27]. Accordingly, it is difficult for retailers to connect with inverter OEMs or agents (such as aggregators) that can control those devices.

However, there are proposed reforms on the horizon in South Australia requiring new solar generating plants connected to the distribution network to be capable of being dynamically export limited and for export limits to be updated remotely[28]. Similarly in Western Australia, new rules require all new and upgraded rooftop solar with an inverter capacity of 5 kW or less to be capable of being remotely managed[29]. Under the South Australian Flexible Exports changes, new and upgrading solar customers connecting in overloaded network areas can choose between a fixed export option, or a flexible export option where the limit varies based on the DNSP's assessment of network capacity in the customer's network location. Elsewhere in the NEM, PV inverters will increasingly require the capability to communicate remotely as the ESB's DER Implementation Plan is delivered over the next three years[30]. The DER Implementation Plan, proposes a phased implementation of technical standards and guidelines to support uptake of enduring DOE capabilities.

As identified in Figure 7, there are three ways that control signals can be sent between parties:

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[27] At https://www.cleanenergycouncil.org.au/industry/products/inverters/approved-inverters

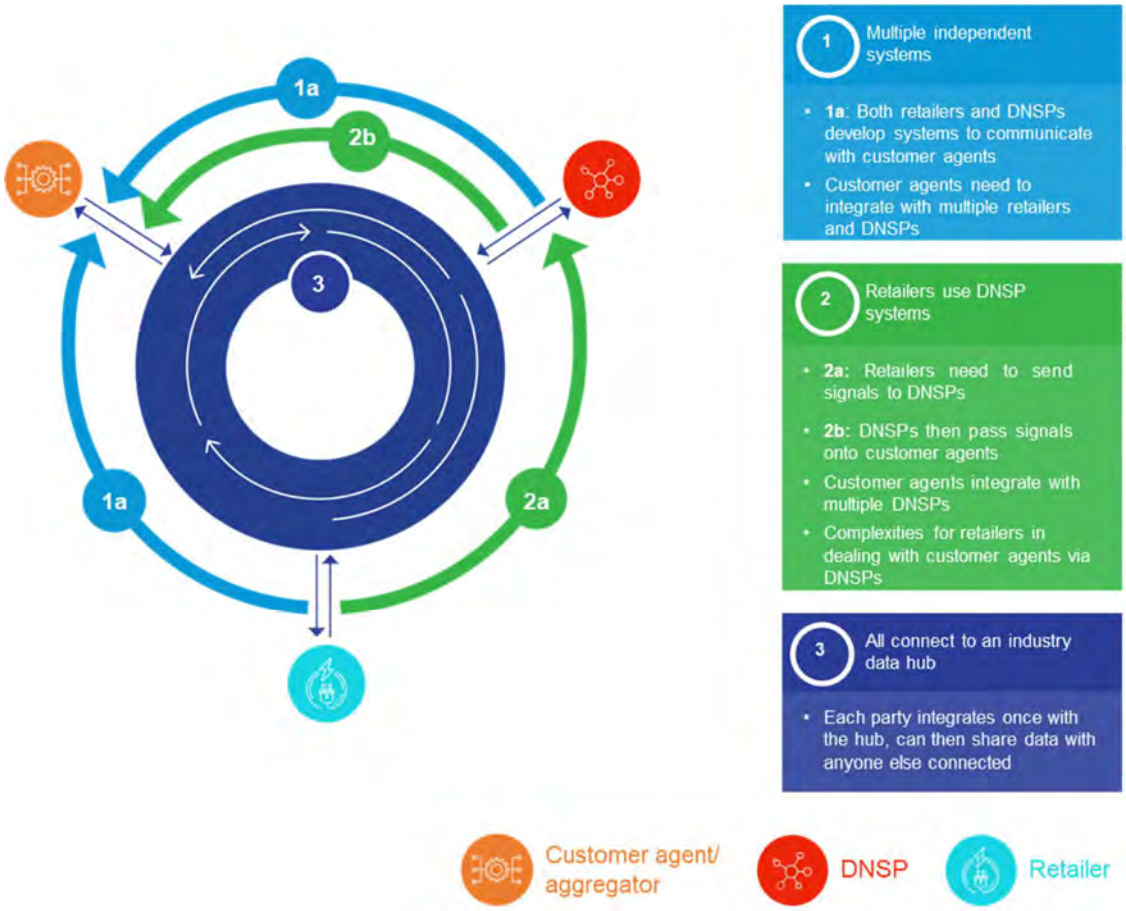
[28] In South Australia, the Electricity (General) Regulations 2012 will be amended to provide for this requirement. Information can be found at: https://www.energymining.sa.gov.au/energy_and_technical_regulation/energy_supply/regulatory_changes_for_smarter_homes/dynamic_export_limits_requirement

[29] At https://www.wa.gov.au/organisation/energy-policy-wa/information-consumers-emergency-solar-management#i-m-planning-to-install-rooftop-solar-how-will-this-affect-me

[30] At https://www.energy.gov.au/government-priorities/energy-ministers/priorities/national-electricity-market-reforms/post-2025-market-design/der-implementation-plan-design-and-implementation-process

- Both retailers and DNSPs could establish separate systems to communicate with customer agents to reduce exports to the grid.
- Retailers could connect with each DNSP's server, and request DNSPs to send signals to agents of their customers' rooftop PV systems. However, to enable scale across the NEM would require retailers integrating with more than a dozen DNSPs.
- A third, potentially more efficient option, is for retailers, DNSPs and customer agents to all connect to an industry data hub through which they can share data and control signals with each other. This third approach is discussed in the following section.

Figure 7 Options for how interactions between DNSPs, customer agents and retailers could be facilitated



4.2.3 Data Exchange Hub

Project EDGE is examining the potential benefits and costs of a data exchange hub approach from two perspectives – a centralised and a decentralised approach (discussed in further detail below as option 1 and option 2 respectively). Energy Web has been engaged to facilitate the practical assessment of both approaches to the data exchange hub. Both approaches would require participants to download Energy Web's open-source software to engage with the hub[31].

[31] Technical information provided by Energy Web for aggregators interested in participating, and interested stakeholders generally, can be found at https://aemo.com.au/-/media/files/initiatives/der/2021/edge-ew-solution-intro-and-info.pdf?la=en

Under a hub approach each party could connect to a common data exchange hub and exchange data and signals with anyone else connected to the hub.

Option 1: Centralised hub (with a broker)

In this model, illustrated in Figure 8, data is exchanged via a centralised broker (AEMO in Project EDGE) who operates the hub and receives and transfers data according to agreed rules. For instance, the DNSP could send DOEs attached to NMIs to the hub; the broker then uses the NMI reference to allocate DOEs into registered aggregator portfolios and sends the appropriate DOEs to each aggregator. This can all be automated but would require a broker to be responsible for executing the process according to the agreed rules.

Figure 8 **Centralised data hub architecture being tested in Project EDGE**

Customer agent/aggregator

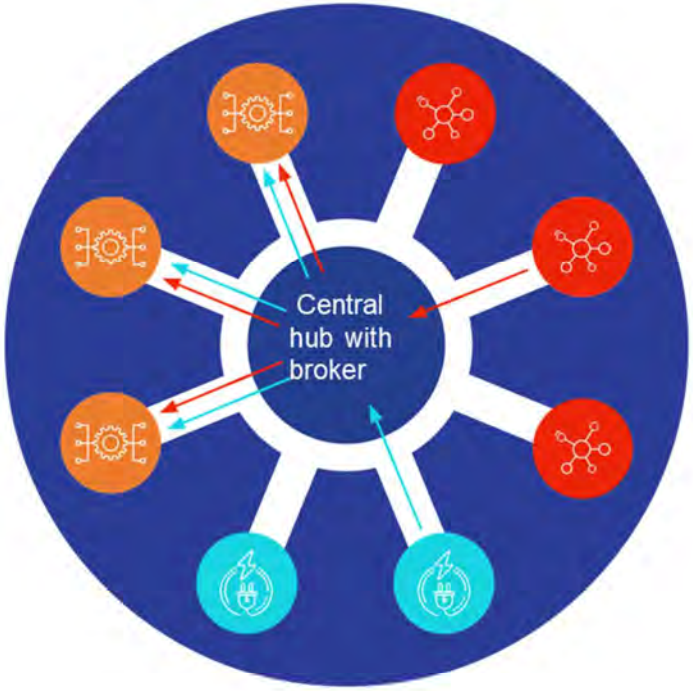
- Operates customers' DER on their behalf - either the original equipment manufacturer or their aggregator – by connecting to the centralised data hub

DNSP

- Connects to the centralised data hub in order to communicate Dynamic Operating Envelopes to customer agents
- DOEs provide customer agents with the operating limits permitted for DER under their control in any given interval
- Connecting to the hub enables DNSPs to send DOEs to any customer agent also connected to the hub

Retailer

- Also connects to the centralised data hub in order to communicate control signals to customer agents
- Control signals will request customer agents to reduce or stop exports from the premises to the grid at certain times (Dynamic Export Limits (DELs))
- In future retailers could also communicate dynamic "free charging" periods to EVs in their customer base (Dynamic Charging Signals (DCS))



CHub

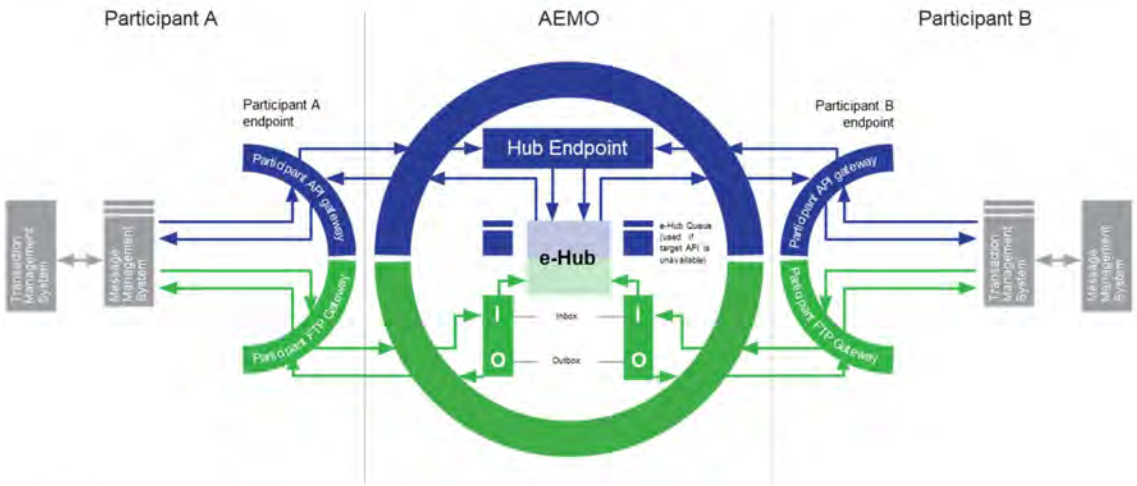
All connect to an industry data hub

- In a centralised data hub a broker is required to operate and manage the hub
- The broker receives data/ messages from participants and directs them to the correct recipient
- For instance, the DNSP could send a list of DOEs linked to NMIs for a time period, and the broker would package and send the DOEs for each customer agent (using NMIs in their portfolio)

In the centralised approach, all data is provided to, and stored in, a centralised hub which may be hosted within a single organisation's environment, into which parties integrate and can access required data based on their role-based permissions and credentials.

AEMO operates an existing e-Hub in this way, which facilitates data and messages being transferred between industry participants (business-to-business) to facilitate the retail market in the NEM[32]. The e-Hub conceptual infrastructure is illustrated in Figure 9. A similar centralised hub approach is being tested in the UK by ElectraLink, a company that is co-owned by six Distribution Network Operators, through an innovative data provision and standardisation project called Flexr[33].

Figure 9 High-level view of existing e-Hub conceptual infrastructure



* Participants can either use FTP/API interfacing method (or both)
* Participant systems are illustrative only. Participants may meet business and technical requirements for interaction with the e-Hub and other participants in any mannner they choose - provided that transaction formats, transaction models and connectivity requirements are satisfied

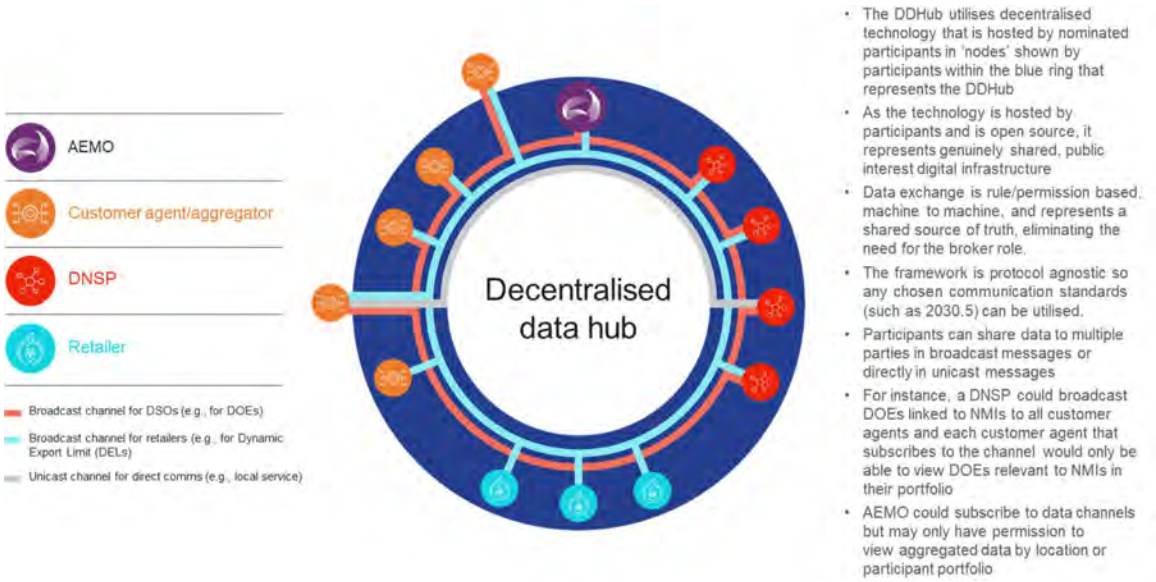
Option 2: Decentralised Data Hub (DDHub) with digital identities (no broker)

Conceptually, the decentralised hub approach removes the need for a centralised broker role, both in terms of hosting the hub and in operating the hub to transfer data through it. The DDHub concept is illustrated in Figure 10.

[32] At https://aemo.com.au/-/media/files/electricity/nem/retail_and_metering/b2b/2018/b2b-smp-technical-guide.pdf?la=en&hash=E99BF018F014EC32B792A7D1D55C0D23

[33] At: https://www.electralink.co.uk/flexr/

Figure 10 Decentralised data hub conceptual model



4.2.3.1 Hosting the DDHub

In Figure 10, the dark ring represents the decentralised hub and the circles within the ring represent participants hosting nodes that facilitate the DDHub. Circles that are outside the ring but connected to it represent participants that are integrated with the hub but are not hosting components of the shared digital infrastructure. Any type of participant could be allowed to host a node but hosting rights would be defined in the governance structure for the DDHub.

It may be possible that instead of the hub being hosted by one party (like AEMO hosting the e-Hub[34] for example), a decentralised hub could represent shared digital infrastructure where multiple parties host nodes that facilitate the exchange of data, messages, and services. This is hypothesised to mitigate the risk of a single point of failure as the loss of one node would not disrupt the ability of the decentralised hub to continue operating. For this to eventuate, it is likely that node hosts would need to be incentivised to provide this service.

4.2.3.2 High-level architecture for the DDHub

Three key components compromise the DDHub:

1. Distributed Ledger Technology (DLT).
2. Digital and Decentralised Identities (DID).
3. Decentralised messaging service.

DLT

The DLT establishes an immutable, tamper-proof ledger that acts as a single source of truth for asset, organisation, and owner standing data. The DLT will not be used for storing operational market data such as DOEs, bidirectional offers, dispatch instructions or telemetry as this would slow the data exchange performance to an unfeasible latency.

[34] At https://aemo.com.au/-/media/files/electricity/nem/it-systems-and-change/2020/guide-to-aemos-ehub-apis.pdf

The DLT's core facilitating feature for the DDHub is to establish trust among DDHub participants through a transaction signature process. The DLT is designed to provide a highly secure and protected – an immutable and tamper-proof – 'register of truth' (trust and security is further discussed below in relation to digital identities).

DID

DIDs are used to create identities, verify attributes and credentials, establish relationships, define roles and permissions, and anchor this information to the DLT in a way that is highly scalable. The NMI represents a digital identity for the customer connection point, and each NMI can be linked to a customer authorised agent to receive the DOE and act on their behalf. These agents would register with the decentralised hub and have a DID of their own, as would each DNSP, AEMO, and any other party that registers. This allocation of roles would be defined through the governance framework that determines the registration and switching process (including the data or credentials that must be verified to acquire a given role), and the DIDs enable trusted exchange of data in the operational timeframe. The DLT is used to 'anchor' DIDs and associated verifiable credentials – digital evidence like non-digital items such as a passport, that enable proof of the entity or individual conducting the transaction. Each DID 'signs transactions' to prove the authenticity and authorisation of the entity which controls the DID. Permission types and verifiable credentials are utilised to validate whether one DID that is instructing another DID to do something is a genuine entity that has the permissions it claims. The DLT has been selected to test this use case on the hypothesis that it provides strong cyber security capabilities because an attack on a decentralised network with no single master administrator requires penetrating the majority of DLT nodes simultaneously to gain control and overwrite existing entries[35].

Decentralised messaging service

The decentralised messaging service enables participants to use a common data model together with a common set of commands and shared interfaces, to exchange data with each other directly (i.e. not via a broker), or broadcast to a network of participants (who subscribe to data that is within their control – e.g. NMIs they manage). In the Project EDGE DOE communication use case, the DDHub avoids the need for AEMO to receive DOEs and forward them to relevant aggregators. Rather, it contains business logic that enables partitioning of DOE broadcasts, so they route directly to respective aggregators (based upon their control of NMIs). The DDHub design is schema-agnostic so it can accommodate any type of schema or communications protocol agreed by the industry – for instance the DDHub could accommodate the 2030.5 CSIP-Aus for device-level communications. In contrast to a central hub (which can also be implemented in a schema-agnostic way), the DDHub allows for participants to configure their own direct (bilateral or multilateral) communication channels with their preferred protocols without requiring an administrator or broker to manage it for them. Figure 10 above illustrates how multiple retailers and DNSPs would communicate through the DDHub with multiple customer agents active across various DNSP regions. Project EDGE is aligning to, and building on, this schema for communicating DOEs. In the DOEs example, the DNSPs would publish DOEs linked to NMIs to a broadcast channel in the DDHub, and the customer agents/aggregators would subscribe to that broadcast channel to receive the DOEs only for the NMIs that are registered in their portfolio. This capability is enabled by the DIDs that provide secure identities for all participants, devices and owners. Refer to Section 2.3.1 for a discussion on lessons learned regarding

[35] For literature discussing DLT (blockchain) security, see https://www.sciencedirect.com/science/article/pii/S2352864818301536, Section 4.2; and https://arxiv.org/pdf/1903.07602.pdf, Section 3.2.2

the 'chunking' of DOE updates to reduce the volume of data transmitted to facilitate scalable DOE exchange.

4.2.3.3 Decentralised hosting in practice

The DDHub is designed to operate across multiple nodes or service providers and infrastructure (i.e. servers) that comprise a network. This differs from legacy applications that operate on a single server or cloud environment or store their data in a single database that is hosted and managed by a single, central provider. This decentralised approach is designed to build resilience even compared to 'distributed' architectures, in which applications and data are managed across multiple physical data centres by coordinating infrastructure across multiple service provider environments. This is to avoid any single point of failure across the solution.

To host nodes under a decentralised approach simply requires participants (and others) to provision a server (physical or virtual) that hosts the service. This is similar to how a cloud-based or on-premises provider currently does now. This could also facilitate the culture of shared ownership of the industry's digital infrastructure.

Decentralised hosting avoids 'vendor-lock-in' and as such fosters competition that incentivises developers and service providers to deliver the highest quality services to users. Consumers obtain additional value because decentralisation fosters a competitive environment for delivering technology services. In turn decentralised hosting adds the potential to improve the quality of service, drive innovation, and through lowering barriers to new entrants, potentially lower costs for consumers.

4.2.3.4 Importance of governance structure

The DDHub model is hypothesised to be a feasible public interest, shared digital infrastructure that could facilitate efficient, scalable and low-cost data exchange between industry participants.

However, the technology cannot operate without an appropriate governance structure, which itself would have to be set out in the NEM regulatory framework.

Establishing the governance of this digital infrastructure model would require industry collaboration and consultation to determine the appropriate roles, access and capabilities required. For example, the governance framework for the e-Hub, which facilitates business-to-business (B2B) data exchange in the retail market, established the Information Exchange Committee as an independent statutory body under the NER that is responsible for developing and making recommendations on changing B2B Procedures[36].

4.2.3.5 Potential for decentralised applications (dApps)

While the DDHub is the foundational layer of digital infrastructure that facilitates digital and decentralised identities as well as data exchange, participants can build independent applications (dApps) on top of this foundation to drive innovation in DER integration and deliver further value to industry and customers. Since the dApps would be integrated with the DDHub infrastructure, the trust and security associated with DIDs can leverage the confidence that entities and services offered and exchanged via any dApp are authentic and authorised.

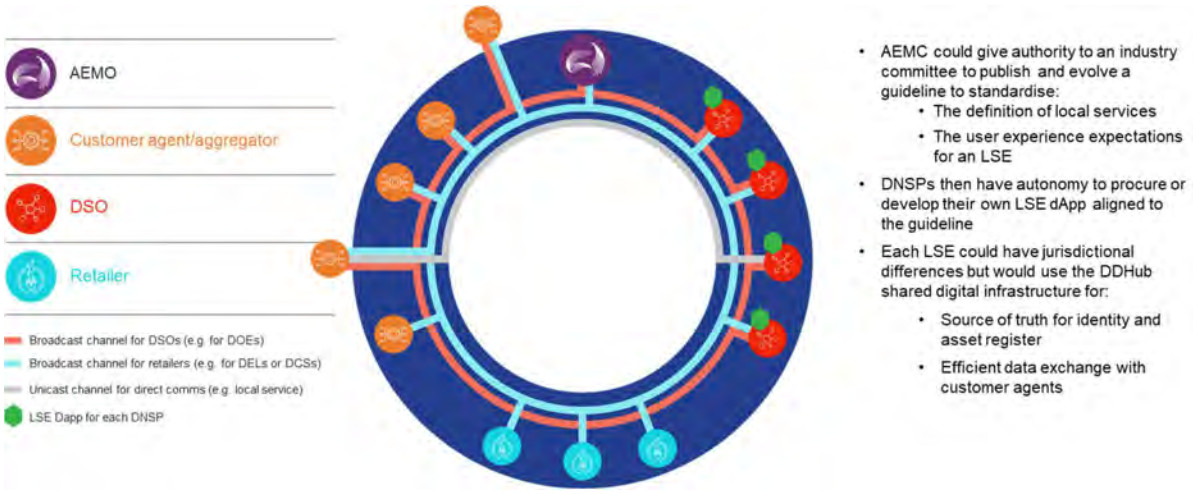
[36] At https://aemo.com.au/consultations/industry-forums-and-working-groups/list-of-industry-forums-and-working-groups/information-exchange-committee

In the context of Project EDGE, the LSE is a potential dApp that facilitates the structured procurement of local network services between AusNet and aggregators. This structured procurement aligns with the current practice of procuring network support services in bilateral contracts, rather than in real-time markets. However, the LSE dApp could eventually evolve to enable this trade to be facilitated through smart digital contracts that are replicable and scalable.

Project EDGE aims to demonstrate that local network services can be defined using a set of common characteristics. It is envisaged that in future, an industry guideline could aim to standardise the definition of local network services. This would enable aggregators operating across the NEM to deliver similarly defined services to each DNSP, reducing barriers to DER providing local network support services at scale. Each DNSP could have the autonomy to develop or procure their own LSE dApp that aligns to the standard guidelines but also enables DNSPs to operate their own LSE that procures local flexibility or network support services customised to their specific circumstances.

Under a decentralised data hub model, AEMO would not be required to have any role in the trade of local network services between DNSPs and aggregators. However, if each LSE is integrated to the DDHub, and the governance arrangements support the sharing of aggregated data with AEMO, then AEMO could have appropriate aggregated visibility of the scheduled trade of local network services across the NEM to support operational forecasting, contingency planning and overall system operation. Figure 11 shows the potential for LSE applications.

Figure 11 Potential for Local Services Exchange decentralised applications



4.2.3.6 Further potential benefits associated with the DDHub concept

There are a number of potential further benefits associated with the DDHub concept that Project EDGE is seeking to explore:

- Cyber security and trust – the DDHub applies DLT to mitigate costs and inefficiencies associated with data replication and reconciliation. This technology is highly cyber secure as the consensus mechanism means a majority of nodes would have to be hacked (simultaneously) to 'penetrate' DLT and overwrite existing data. Organisations eligible to host validator nodes could be defined in the governance structure.
- Shared digital infrastructure – the DDHub could be open source, public interest infrastructure that would avoid ongoing licence fees and reduce barriers to entry for new participants. It could

facilitate multiple providers being able to build applications on top of its foundation, thereby driving innovation and potentially lowering overall system costs.

- Scalability – the DDHub is designed to be highly scalable to accommodate the exchange of data amongst many industry actors, relating to millions of devices (in a future with over 100 GW of distribution-connected resources), using a common data model and common set of commands. As the DDHub is facilitated through machine-to-machine interactions, the volume of data exchanges can scale as quickly as required.
- Dynamic DER Register – incorporating the next evolution of the DER Register (DERR) into the DDHub could enable the DERR to become dynamic. Currently the DERR collects asset information only on installation, but a dynamic register could also hold information such as inverter settings or dynamic tariff arrangements for example. As the DDHub utilises DLT, the information represents a reliable shared source of truth for an asset data register that is consistent across the industry.

4.3 Linkage with cost benefit analysis

The CBA will consider the long-term costs and benefits of various approaches to distributed level data exchange between DNSPs, customer agents/aggregators and retailers in a high DER future informed by the Draft 2022 ISP's most likely Step Change scenario.

4.4 Lessons learned

Key challenges and lessons learned from the design process include:

- Complexity – it is challenging to communicate the benefits and trade-offs of the different approaches effectively and clearly without losing the messaging in technical details. To ensure industry has a clear understanding of the benefits and values (not only technical but commercial and governance as well), there is a need to invest considerable time in engaging with stakeholders and taking them along the journey of understanding.
- Barriers to entry – adoption of the DDHub may be impeded by the time and cost of market actors investing in capability to interface with this approach. These barriers may be helped by starting with a single host (e.g. AEMO), with a few participants 'subscribing' to integrate. Over time, participants could elect to host infrastructure (or continue to subscribe) and develop additional use cases and independent applications.
- Cost efficiency – the approaches will require industry to invest in new technologies. Therefore, to support cost efficiencies it is important the CBA gathers robust evidence on the scalability of different approaches to inform decision-making.
- Collaboration - it is hypothesised the DDHub would enable more efficient and scalable exchange of data between distribution level actors and enable consistent command signals to be sent by DNSPs for dispatch and delivery of local network services. Due to the central role distribution level actors would have under the DDHub approach, there will be a need for significant collaboration across the distribution end of the energy supply chain.
- Data security – AEMO, DNSPs and many actors in the energy sector operate critical infrastructure and as such have significant security considerations and obligations. Therefore, a key factor in exploring the different approaches will be consideration of the security settings of critical infrastructure entities in relation to decentralised technology.

- Innovation – under the DDHub, every layer of the supply chain – role and asset – would have a DID. This enables trusted data exchange in operational timeframes at every layer of the supply chain and creates a flexible framework for innovation, including innovation opportunities with business models, data access, and applications. For example, dApps have the potential to drive innovation in DER integration to deliver further value to consumers and each actor has the autonomy to develop or procure their own products. Another example is the ability for any entity to interact with any other while the DIDs provide the audit trail for service verification among actors and markets. This creates innovation opportunities regarding trust and transparency – increasingly significant values in relation to data for consumers. DIDs enable innovation comparable to 'single sign-on' functionality – any given actor can use one ID and set of credentials to access many different applications/systems without having to duplicate registration processes (or data).

5 Australian Energy Market Operator

5.1 AEMO's role in Project EDGE

AEMO has a statutory function to establish and operate a spot market[37] and to operate a central dispatch process[38]. As coordinated DER and demand side participation (DSP) is anticipated to rapidly increase in scale, AEMO must consider how to operate the central dispatch process with very high penetrations of DER influencing both market and power system operations. Refer to the discussion in Section 4.1 on the forecast NEM capacity by 2050 under AEMO's Draft 2022 ISP Step Change scenario, and its potential implications.

The forecast changes to generator dispatch and minimum demand are projected to push the power system to its limits and will change the way system security is maintained. The forecast increase in DER and DER storage has the potential to reduce the need for utility-scale investments by networks to maintain system security and reliability if they are effectively coordinated, but this will require consumers to adopt and trust new smart technologies that enable active management of consumer devices. The willingness of consumers to adopt these technologies and lower their consumption through DSP during high-demand periods will have a significant influence in maintaining system security and avoid involuntary load shedding[39].

It is expected that DER portfolios will be required to provide greater operational visibility to AEMO, possibly via participating in the central dispatch process (as envisaged in the Scheduled Lite reforms[40]). Distribution network limits will need to be considered in the wholesale dispatch process (via adopting a national approach to implementing dynamic operating envelopes). AEMO will need to engage with aggregators and DNSPs to identify the most efficient ways to achieve these outcomes.

In Project EDGE, research related to the DER wholesale integration function aims to understand how to optimally integrate DER via aggregators as new market participants into existing wholesale markets, while maintaining power system operability as outlined in AEMO's Power System Requirements[41].

In the context of Project EDGE and the future DER Marketplace, AEMO's primary focus relates to wholesale market interactions. AEMO has no role in the trade of LSE outside of efficiently facilitating the associated data exchange. In time, the extent of AEMO's role in the data exchange function could change depending on whether the centralised or decentralised approach were adopted. The different approaches are detailed in Chapter 4.

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[37] National Electricity Rules 3.4

[38] National Electricity Rules 3.8.1

[39] At https://aemo.com.au/-/media/files/major-publications/isp/2022/draft-2022-integrated-system-plan.pdf?la=en, Section 4

[40] At https://esb-post2025-market-design.aemc.gov.au/32572/1629945838-post-2025-market-design-final-advice-to-energy-ministers-part-c.pdf, Section 2.6

[41] At https://aemo.com.au/en/newsroom/news-updates/power-system-requirements-report

Refer to Section 3.1.1 for a discussion on AEMO's roles and responsibilities in Project EDGE, to continue operating the power system in a secure and balanced way.

The Project Partners are investigating a spectrum of approaches that span a simplicity-efficiency trade-off continuum, from relatively simple and lower cost to implement, but relatively inefficient, to more complex, higher cost to implement and more efficient. Efficiency refers to both the level of market efficiency and the level of network utilisation (that is, how close to the true network limits the market can securely operate).

The progression of system efficiency and cost and complexity are shown in:

- Figure 12, relating to approaches for incorporating distribution network limits in the wholesale dispatch process.
- Figure 13, relating to approaches for obtaining visibility of price responsive DER and scheduling aggregator DER fleets through the existing central dispatch process.

Figure 12 Spectrum of the simplicity-efficiency trade-off for distribution network limits and wholesale dispatch

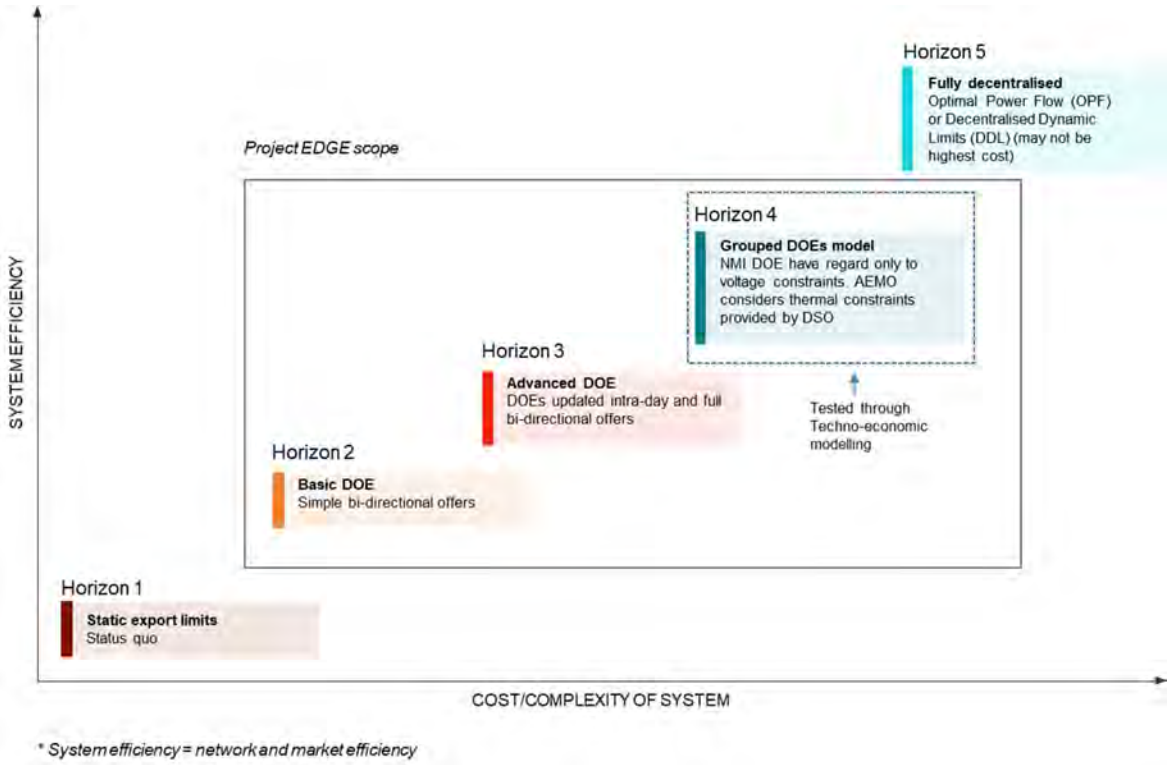
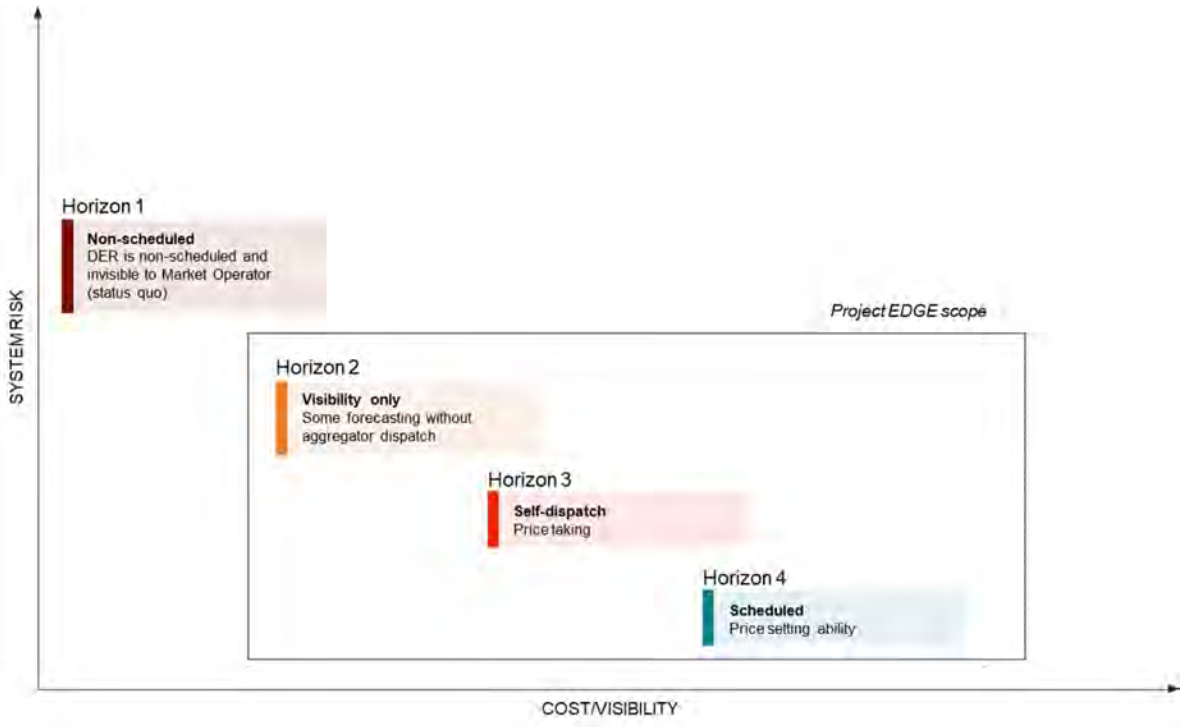


Figure 13 Spectrum of the simplicity-efficiency trade-off for dispatchability



5.2 Preliminary findings

Stakeholder engagement and literature review activities have provided preliminary findings on interoperability and communications, and aggregator participation and the dispatch process.

5.2.1 Interoperability and communications

The project scope regarding interoperability and communications is limited to the data exchange process. The different approaches for this function are discussed in detail in Chapter 4. Preliminary findings on interoperability and communications between AEMO and stakeholders (e.g. DNSPs, marketplace participants, and other third parties such as OEMs) suggest that the decentralised data hub model may reduce complexity compared to the point-to-point communication methodology.

An approach that is protocol-agnostic but inherently applies a common data model with common command functions enables simpler and broader participation because it does not require prospective parties to adjust their processes to participate and communicate with different parties. It also means the approach can align to multiple communication and technical standards relating to inverter based DER devices to enable interoperability (i.e. standards on how devices communicate with each other so customers can easily switch between providers), further facilitating broader participation.

With respect to data, preliminary findings indicate that there is a need to align to an agreed standard for communicating DOEs to provide efficiency at scale. Refer to the discussion in Section 2.3.1 for lessons learned on common communication protocols and approaches to facilitate scalability of data exchange.

Regarding security, the use of DIDs anchored in the DLT can verify that an actor has the required authorisation to access messages and data (and can only access and communicate with other users

according to their role). The use of DLT also maintains traceability of messages, actions and services. Refer to Section 4.2.3.2 for a discussion on DIDs and DLT. The potential cyber security risks and/or benefits of different approaches to data exchange will be explored further in future knowledge sharing reports.

5.2.2 Aggregator participation and the dispatch process

Aggregators will not be able to meet all or most of the requirements for participation without the need for some investment to uplift their capabilities and systems. For example, aggregator participants will be required to meet the data integration and sharing requirements of the Project EDGE data specification and would therefore need to commit to developing the capability to meet the data specification. This includes capabilities to provide AEMO with DUID telemetry data, which is needed for operational visibility and dispatch conformance monitoring. DUID is the aggregation of all DER assets for a particular aggregator, and as such requires aggregators to provide data aggregated for the whole portfolio. To access and exchange data with the Project EDGE DER Marketplace, aggregators will need to download and install the open-source Energy Web container.

Aggregators must also develop the portfolio management and coordination capability to meet the needs of new service delivery and optimise value for customers from DER. Aggregators will need to gain customers in constrained network areas to provide LSE services and grow their DER fleet. This will require aggregators to consider communication and marketing approaches as customers' DER participate in different ways. This means not just maximising self-consumption but aggregating their customers' discretionary DER capacity to respond to wholesale market and local network needs while remaining within NMI level DOEs. For many aggregators this represents an evolutionary step in operations, commercial model and customer value proposition.

5.3 Lessons learned and challenges

Project EDGE is providing a robust evidence base to inform regulatory and business decisions. Through its research activities Project EDGE will identify key issues that may reflect conflicting preferences on approaches that will need to be solved by the broader industry as a future DER Marketplace matures and evolves.

DOE allocation level

One key issue identified so far is the DOE allocation level. The Distributed Energy Integration Program (DEIP) Dynamic Operating Envelopes working group agreed on the principle that DOEs can be initially allocated at the connection point to the network (regardless of the number or configuration of devices behind the connection point) as a first step in DOE roll out[42].

- The primary basis for this principle is that it reflects the current connection framework wherein DOEs are enabled by current customer-network connection agreements.
- The DEIP notes that this may have implications on retail product innovation and customer choice that need further consideration, particularly as proposed flexible trading arrangements reforms that involve multiple meters at premises are implemented[43].

[42] At https://arena.gov.au/assets/2022/03/dynamic-operating-envelope-working-group-outcomes-report.pdf, page 15

[43] The Flexible Trader Model 2 (sub-meter connection point) proposed by the ESB. Details can be found at https://esb-post2025-market-design.aemc.gov.au/32572/1629945809-post-2025-market-design-final-advice-to-energy-ministers-part-b.pdf, page 86

- The two approaches may lead to different preferences between networks and aggregators as reforms take effect.
- These differing preferences will need to be solved together by the broader industry with consideration for the long-term interest of all stakeholders and consumers.
- Project EDGE's research activities on DOE allocation will provide an evidence base to inform these industry decisions.

Compliance mechanisms

Another emerging challenge for integrating fleets of DER bidding within DOEs into NEM central dispatch is determining an effective compliance mechanism. Currently, AEMO operates a Security Constrained Economic Dispatch (SCED) in which market actors' bids (MW) cannot be dispatched outside of the transmission network constraint under which they operate[44]. AEMO calculates these constraints based on input from TNSPs and dispatches the most economic bids underneath, partially dispatching a bid if required[45]. Potential mechanisms considered by the project include:

- Real-time validation of aggregated DOEs for an aggregator's portfolio versus wholesale bids received. Bids are constrained down to within aggregated DOE quantity if they exceed.
- Alternative compliance incentives (such as high penalties for non-compliance evaluated ex-post).

Real-time validation is done at the portfolio level (aggregation of all aggregator NMIs), providing a coarse check that cannot determine whether individual NMI DOE limits were breached.

- This is unlikely to suit DNSPs.
- If the DOE is Net NMI and the bid is Flex (discussed in Section 2.3.1) then real-time validation is not possible, only ex-post. An ex-post assessment-only would require a degree of trust that aggregators will bid within their DOEs and that DOE compliance incentives are sufficient to ensure that system security is not at risk.
- At high wholesale market prices, aggregators may be tempted to export beyond their DOE for commercial benefit.
- Another consideration is that high penalties enforced on this nascent market could stifle its development.

5.4 How AEMO interacts with the EDGE DER Marketplace

AEMO's primary interaction with the DER Marketplace is within the wholesale integration function. The initial stages of the project and marketplace operation will be to test the basic application of DOEs in an off-market wholesale dispatch process. In the field trial an Advanced DOEs model will test more frequent DOE calculations on the trading day leading up to the dispatch interval and sophisticated aggregator bidding. Desktop studies will assess impacts from an increase in complexity in line with the simplicity-efficiency trade-off. These desktop studies will assess the Grouped DOEs Model and whether there is value in pursuing economic optimisation within the DOE calculation. The Grouped DOEs Model introduces separate thermal capacity limits for a given network node provided by the DNSP and represented by a group of NMIs. Aggregators bid 'unconstrained' and dispatch

[44] At https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/congestion-information-resource/constraint-faq

[45] At https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/congestion-information-resource/constraint-faq

instructions are produced through a grouped-level security constrained economic dispatch process to maximise the economic efficiency and utilisation of the network.

The extent of AEMO's interactions is influenced by the efficiency-complexity progression model applied. The progression of these interactions is summarised in Table 1 below. Certain high-level interaction activities continue through each progression model, however, the details of the activities within these interactions change as the complexity progresses. For example, the high-level interaction activity of pre-solving under the Grouped DOEs Model includes additional pre-solving elements such as economic optimisation of bi-directional offers under the distribution network thermal constraint in question. Table 1 summarises these interactions at a high-level.

Table 1 AEMO's interactions with the DER Marketplace through the wholesale integration function

Progression model	Interaction with aggregator	Interaction with DSO
Basic DOEs marketplace	Validate bi-directional offers submitted by aggregators against aggregated DOEs for their portfolio.	Receive DOEs from DNSP.
	Send aggregators dispatch instructions based on wholesale optimisation.	
	AEMO receives operational data from aggregator to verify dispatch.	
	Assess compliance against dispatch target (and aggregated DOEs). Take appropriate action in the event of non-compliance.	
Advanced DOEs Model	Same as above but in closer to real time	
Grouped DOEs Model	Additional interactions	
	Aggregators bid per thermal constraint (multiple).	Receive thermal constraints from DNSP.
	Pre-solve bid stack for group of NMIs under thermal constraint before solving wholesale merit order.	
	Provide 'grouped' dispatch instructions corresponding to NMIs under thermal constraints.	AEMO shares dispatch outcome with DNSP.

5.5 Design and technology

The primary design and technology focus for AEMO in Project EDGE relates to the wholesale integration function and data exchange. The design process for wholesale integration includes the requirements for on-boarding and integrating additional aggregators into the project. The perspective of the Market and System Operator regarding the approaches to the technology needed to enable and facilitate the wholesale integration and data exchange functions is discussed in Chapter 4.

5.5.1 Trial participation requirements

AEMO has published an expression of interest for a minimum of two additional aggregators, at least one of which must also be a licensed energy retailer, to participate in Project EDGE[46]. To support the selection and registration of these aggregators, AEMO has published the requirements for participation. Broadly, aggregators will be required to:

- Participate in the Project EDGE wholesale market and LSE.
- Test data exchange at scale via the DER Marketplace.
- Contribute to knowledge sharing and CBA deliverables and learnings throughout the onboarding, participation and post-trial activities.
- Participate in the customer insights study.

Aggregators will also need to demonstrate they can meet the data requirements to facilitate participation in the DER Marketplace operation and to deliver wholesale and local services, including onboarding and enrolment, market participation, operational visibility, and DUID telemetry data requirements. Additionally, aggregators will need to demonstrate ability, or potential, to meet wholesale service qualification requirements (capabilities of the aggregator's DER portfolio to deliver, measure, and verify DER services), and ability to uplift their capabilities to deliver the services being tested in Project EDGE. Aggregators will also need (or willingness to acquire) customers in the target area (AusNet's Victorian electricity distribution network), agreements in place to enable data sharing, and participation in the customer insights studies.

Participation will expose aggregators to new technology, approaches and solutions that will provide the evidence-base to inform current and future market design initiatives supporting the energy transition. It also provides an opportunity to test, develop and learn how to deliver services innovatively and efficiently in a simulated off-market environment without the risk of adverse consequences or financial penalty. Through participation, aggregators will gain direct insights into the customer experience and how a future DER Marketplace may operate and can contribute to the future design of the aggregator role. Accordingly, aggregators will benefit from valuable experience and insights that place them at the forefront of the energy industry's transition to a high DER future.

[46] At https://aemo.com.au/initiatives/major-programs/nem-distributed-energy-resources-der-program/der-demonstrations/project-edge. This link includes information to support the selection and registration of interested aggregators, including data specification, Energy Web solution information, and other technical requirements.

6 Distribution System Operator

6.1 AusNet's role in Project EDGE

AusNet fulfils the role of the DSO in Project EDGE. It is responsible for developing and testing new DSO functions. The expanded role enables a marketplace where connected DER can access available network capacity dynamically to provide wholesale energy market and local network services via aggregators acting on behalf of DER owners. The learnings from Project EDGE can inform DNSPs on the capabilities and functions needed to evolve into the DSO role and develop their strategies and visions to realise it. Refer to Section 3.1.2 for a discussion on AusNet's roles and responsibilities in Project EDGE.

In collaboration with the Project Partners, AusNet is also responsible for designing, developing, testing, evaluating and reporting on alternative ways of achieving its functions. The evidence gained can be used to inform related industry reforms, and DNSPs' ability to develop future capability that is needed to support the changing energy supply ecosystem.

6.2 Preliminary findings

AusNet's findings relevant to DNSPs to date are limited to the key activities undertaken so far. These relate to the determination of the DOE and its inter-relationships with the trial market operating model options, the design and definition of local network services, and the supporting processes. In addition, some conclusions can be drawn from the collective design and procurement activities.

6.2.1 Industry engagement

AusNet has engaged extensively with industry and stakeholders from project inception. The primary forum for DNSPs is the Networks Advisory Group (NAG), whose members include DNSP representatives from across Australia, along with Energy Networks Australia (ENA), the national industry body representing Australia's electricity transmission and distribution and gas distribution networks, the University of Melbourne (a technology and knowledge sharing partner in Project EDGE), Nous (the Project EDGE independent project manager), ARENA, and invited guests from other related pilots and trials in the area (e.g. Evolve DER)[47].

Details of key insights from various engagement activities have been published in the Project EDGE Lessons Learned Report #1[48]. Subsequent distribution network industry engagement activities have led to additional preliminary findings relating to local services.

[47] At https://arena.gov.au/projects/evolve-der-project/

[48] At https://aemo.com.au/-/media/files/initiatives/der/2021/project-edge-lessons-learned-report-1.pdf?la=en

Definitions

Further thought needs to be given to defining a service and a condition of network connection (e.g. whether voltage management services should just be part of a connection agreement, and whether 'reactive' support to deal with voltage issues should be free).

Priority of network integrity and security

- There are perceived risks in passing over 'network responsibility' to aggregators (aggregators favour market over network, but network integrity and stability always has priority over market operation).
- More attention needs to be directed at how over/under supply of local network services is managed.
- There is a need for service prioritisation in the context of local network services and the wholesale energy market. See Section 3.3.1.
- Stakeholders hold a general view that network access 'capacity' trading still needs to be explored (considering thermal limits not voltage quality of supply constraints).
- Security and cyber security remain a key area of concern with respect to the Project EDGE data exchange hub approach and requires further consideration.

Measuring value and services

DNSPs will need to develop the capabilities and processes for determining how to value and measure and verify local services provided by DER. Stakeholders identified challenges in how to measure and validate local service performance from aggregated DER. The most common challenge identified was related to whether a 'baselining' technique for measuring aggregated DER service delivery could be applied, and if so, determining the appropriate methodology and assessment method. Additionally, while there are established methodologies for valuing demand management services, the emerging introduction of voltage management services does not appear to be straight-forward, especially within the context of DER participation in wholesale energy market activities which also impact local network voltages.

6.2.2 DOE calculation

There are several concurrent industry trials exploring the calculation of DOEs. However, in Project EDGE the direct interaction of the DOE with active DER market operating models is being tested for the first time. Project EDGE also presents the opportunity to use data from the almost 100% penetration of smart meters in Victoria in calculation of DOEs.

Project EDGE tests a few different options for calculating the DOE as discussed in Section 6.5.1. From the work undertaken to date, there are several key findings relating to the DOE calculation algorithm developed by UoM based on a full electrical network model.

Network data

- The UoM DOE algorithm requires accurate network data to establish the electrical network models (this includes the full topology and impedance models). The data collection and validation process for this has proven to be resource and time consuming, requiring iterative attempts in desktop assessment and in some cases, field investigation. However, innovative approaches for data validation have also been found and will benefit future network modelling

work. Research work is also being undertaken in a parallel project by UoM[49] to lessen the dependency on the electrical network model by using neural network artificial intelligence techniques.

- The DOE algorithm also requires net forecasts of all passive customers (those not participating in the trial) in the networks being modelled. This sometimes includes customers with Type 1-4 meters which have only 30-minute accumulated watt hours (Wh) and volt ampere reactive hours (VArh) consumption data. As such, estimation of the 5-minute interval real and reactive power is an approximation. If the site only has an old accumulation meter read quarterly, there are no means to accurately estimate these values, which effectively reduces the integrity of the DOE calculation.
- Preliminary results from off-line testing of the DOE algorithm suggest that it can reliably calculate available access to the network by DER at the specific site connections if fed with an accurate set of network and customer data, and that the simplified iterative load flow calculation process is fast and efficient.

Impacts of progression model and scale related variables on the DOE calculation

- The DOE calculation algorithm does not require modification to suit different market operating models and cadences (e.g. moving from producing day ahead DOEs to intra-day DOEs only affects the inputs to the algorithm and not the calculation itself).
- The ability to scale the application of the algorithm across an electricity distribution network will greatly depend on the availability of accurate electrical network and complete customer data, and the respective computation capability available to the DNSP (which is primarily influenced by the cadence of updating and publishing the DOE and not the algorithm). It is highly likely that a simplified DOE calculation approach (an alternative to the UoM developed algorithm) may be more efficient for local networks where there isn't a high proportion of active DER customer connections. These simplified solutions (an adapted tactical hosting capacity algorithm developed by AusNet, and a more simplified version using a derived distribution transformer voltage plus active customer measurements) are also being explored within Project EDGE. However, testing is not yet at a stage where findings can be analysed.
- Based on these insights, the UoM algorithm appears to be well suited to DER constrained networks where there is a high penetration of active DER and the benefits of a reliable and accurate DOE calculation outweighs the costs of implementation.

6.2.3 DOE allocation

The allocation of network access capacity to a network connection point is determined by the applied objective function. In Project EDGE, several objective functions are tested, as described in Section 6.5.1.2. A clear finding from the modelling work undertaken so far in the project is that the 'Equal Allocation' objective function results in material underutilisation of the available network capacity for DER when compared with the 'Maximise Service' objective function. In a practical sense, this means that DER resources are being constrained when they do not need to be, and this can have a negative economic impact for all consumers.

[49] At https://c4net.com.au/projects/

6.2.4 Definition and design of local services

Although DNSPs regularly make use of non-network services to manage peak demand or to defer capital expenditure, these are normally via bilateral contracts with set conditions and pricing. A DER Marketplace offers the opportunity for these services to be more transparent, competitive and to provide increased flexibility in their application. Operational activities have not started yet for Project EDGE, and as such the summary findings below are limited to the definition and design of these services.

Definitions and contracts

- Existing bilateral contracts were found to be a logical starting point for the definition of DER market-based load or generation management services.
- Defining network services in 'firmness' categories (high, medium and low) to suit the various network needs (planning and operational) enabled treatment that aligns to natural market forces.
  - High firmness = guaranteed availability and agreed pricing within a longer-term supply arrangement.
  - Medium firmness = negotiated availability and pricing within a seasonal arrangement.
  - Low firmness = uncertain availability and pricing typically set by the market on the day.

Measuring services, beneficiaries, and service delivery

- Determining how to measure and validate performance and delivery of the services is challenging and has yet to be finalised. This difficulty arises because the service provider's assets are coupled with other customer load consuming or generating assets and actions taken to provide the service can be affected by other customer activities. This is also compounded by the service typically being provided and measured at an aggregate level. Traditionally this is managed by applying a baselining technique, however this may not suit an active market environment. Other international jurisdictions appear to be moving towards direct measurement or verification of the aggregator actions in providing the service (i.e. specific measurement of the controlled assets) to overcome this challenge. The risk of the passive customer load/generation behaviour then passes onto the DNSP which in turn may require moderation of the quantum of local service provided.
- Further consideration of the design of medium or low firmness voltage management services to relieve network access constraints driven by market conditions is required. There remains uncertainty regarding the beneficiaries of the service and how to ensure that procurers of the service receive the benefit. The high firmness service is not subject to these uncertainties as it is designed to address standing network constraints (e.g. quality of supply situations that occur without the existence of DER market activity) and is procured by the network if it is economic (i.e. less costly than upgrading the network). There is a level of industry discussion around what constitutes a 'service' compared to the required DER performance standards (i.e. AS4777.2 requires certain volt/var and volt/watt responses which already provide a level of voltage management for the local networks. However, they are not paid services and it is a condition of network connection). The defined high firmness service in Project EDGE is based around a more aggressive response from the DER.

- Due to the extensive effort in setting up accurate network models, a stronger link between customer acquisition and network constrained areas is preferable to improve network modelling efficiency, maximise customer benefits and adequately answer the project's research questions.

6.3 Lessons learned and challenges

Project EDGE will develop and pilot innovative transformation activities for the DNSP community.

Individual distribution network businesses are actively engaged in developing their approach to the integration of DER within their respective networks, and there is an opportunity for Project EDGE to valuably inform and potentially accelerate those activities. ENA has also outlined a DSO vision, illustrated in Figure 14 below, which summarises key future functions and capabilities.

Figure 14 Key capabilities and functions of a DSO outlined in ENA's DSO vision

Source: Energy Networks Association, DSO Vision – ENA briefing to AEMO 5 May 2021

For AusNet, Project EDGE represents not only a demonstration platform and an opportunity to learn, but also an instrument to develop and build key DSO capabilities (like the calculation and publication of DOEs, and the ability to procure DER services in a marketplace context) that will be required in future. In this regard, the project is a flagship initiative within AusNet's DER roadmap.

Table 2 outlines test activities in Project EDGE related to DSO capabilities and functions and provides an indication of anticipated learnings.

Table 2 DSO capabilities and functions tested in Project EDGE

DSO capabilities and functions	Related Project EDGE test activities
System operations • Increased visibility of power flows, loads, and connections at the distribution and reticulation levels. • Smart grid solutions that enable data visualisation, operational forecasting, situational awareness, and	• Project EDGE tests the use of smart meter analogue measurement data (5-minute sampled instantaneous values of current, voltage, and power factor) to provide visibility of the power quality within specific LV networks and to generate operational boundary conditions for active DER operation.

DSO capabilities and functions	Related Project EDGE test activities
the ability to operationally leverage DER related flexibility services for asset optimisation. • Additional network sensors to monitor DER operation at all voltage levels, including the management of local services provided by DER.	• In areas of higher active DER penetration, an additional sensor is introduced at the HV/LV transformer to provide summed current and voltage measurements in near real-time.
Network planning and system management • Advanced network planning models and DER service assessment aligned to sensitivity analysis that understands the magnitude and impact of DER and EV adoption on the network, and the risk mitigation required. • A composite toolkit that considers all available network and 'non-network' options coupled with efficient and economic contract enablement for both long-term and short-term network needs. • Increased coordination of system operations, information exchange and planning across the distribution and transmission levels.	• Project EDGE introduces and tests an LSE facility with standardised network services that can be used by network planners for solving thermal and voltage-related network issues using DER services.
Asset management • Advanced asset risk and integrity management tools enabling dynamic operation of the network to co-optimise DER participation in markets with available network operational capacity. • Active asset and network condition monitoring to detect and react to variations in load and real-time monitoring of network performance.	• Project EDGE develops and tests several approaches to enabling dynamic network operational integrity governance via the publication of DOEs. These developments can inform the appropriate application of fit-for-purpose solutions that enable increasing penetrations of active DER in the distribution network.
Flexibility management • Ability to procure flexibility services for the most cost-efficient system operation. • Market frameworks for ancillary services to encourage participation by DER owners and aggregators, in coordination with Transmission System Operators (TSO).	• Project EDGE introduces and tests an LSE facility with standardised network services in conjunction with an integrated DER Marketplace environment that can enable value stacking by aggregators.
Commercial operations • Digital information channels for customers and marketplace participants. • Digitised platforms for streamlined customer enquiries, connections, and installations.	• Project EDGE can inform the development of the future digital platforms and features that are increasingly required to interact with active customers and market players. • However, these digital platforms are not specifically developed or tested in Project EDGE.

Given the transformational nature of the DER Marketplace, many learnings and challenges can be expected. A key driver of challenges is increased interaction with external parties, markets and resources resulting from the introduction of the DSO role and related functionality. A second driver is an increased dependency on the accuracy, completeness, and use of network topology and electrical measurement data.

The primary challenges experienced by AusNet to date in Project EDGE relate to:

- Data integrity and availability.

- Trial customer-to-network alignment.
- Spectrum of enterprise and ecosystem involvements.
- Resourcing movement.

These challenges have provided valuable lessons and insights DNSPs can learn from and apply as they develop their DSO capabilities and functionality to adapt to the energy transition.

6.3.1 Data integrity and availability

While the availability of smart meter data has greatly improved the accuracy of the network model-based approach for the determination of DOEs, gaps in network topology and data for low voltage (LV) networks require extensive effort to fill. The project will investigate the trade-off between accuracy and effort in future stages of the project. There have been challenges relating to the accuracy and completeness of information about LV networks, accumulated energy consumption data from non-smart meters, and obtaining active and reactive power data for all modelled customers.

Accuracy and completeness

A foundational challenge is the accuracy and completeness of the existing information pertaining to the LV networks. Historically there has not been a need to have reliable and exact network data for the precise customer connection points (such as phase, LV circuit, distribution transformer). As a result, the relevant information in the utility systems is typically incomplete and may not have been kept up to date as topological changes were made over time. As this information is required for the calculation of DOEs, significant effort was invested to validate the actual state of the electrical connectivity, either via data analytics or field inspection.

Availability

Another related challenge is the availability of energy and analogue measurement data. In Victoria, almost all residential customers have smart meters installed and this data is extremely valuable for the trial. However, non-residential customers typically have Type 1-4 meters installed, which only provide accumulated energy consumption data in 30-minute intervals without any instantaneous measurements of voltage and current. Accordingly, the measurement data set for determining the DOEs is incomplete where there are Type 1-4 meters within the specific network compared to areas with smart meters.

In cases where instantaneous analogue measurement data was not available from a Type 1-4 meter installation, a portable power quality meter was installed to capture two weeks of reference data for forecasting purposes. Additionally, where a customer has an old accumulation meter which provides quarterly read energy consumption only, a simple estimated usage profile was used. For multiphase customers, AusNet did not always have information confirming the phase to which the DER is connected. As DOEs are calculated per phase, AusNet made the decision to publish the minimum of the phase DOE in the first instance. This decision will be reviewed as the trial progresses to ensure there is not an unnecessary constraint on the active DER.

Lessons learned

- Significant effort through data analytics or field inspection will need to be invested to validate existing LV network information.
- DNSPs will need to consider how to obtain and account for active and reactive power data for customers with Type 1-4 meters.

6.3.2 Trial customer-to-network alignment

Another challenge faced by AusNet in the project has been aligning target areas for trial customer recruitment with real opportunities to practically test the DOE options and the local network services.

A key objective of the DER Marketplace trial is to produce practical evidence that can inform industry reform. It is thus important that the recruitment focus for customer-to-network relationship results in operational scenarios where the various Research Plan hypotheses can be authentically tested.

There are several versions of the trial market operating models and several different network services being tested. As such, it was complex to align these to specific network contexts, and to have regard for what represents an attractive aggregator customer in the trial because the opportunity for overlap reduces with each individual requirement.

The approach initially adopted was to apply a range of 'network' and 'customer' filters using data analytics on available DNSP data to identify 'attractive' local networks for the trial. However, this was found to be too restrictive on potential customer recruitment by aggregators. The process was then simplified to identify, from a network perspective, LV and high voltage (HV) networks where DER hosting capacity was severely constrained.

Lessons learned

- An approach that identifies LV and HV networks with severely constrained DER hosting capacity will provide real opportunities to test the DOEs and the relationship with the market operating model options. However, it might not ideally suit the testing of the various local network services, some which could still be modelled.

6.3.3 Spectrum of enterprise and ecosystem involvement

Due to lead-time required in the Request-for-Tender process, the project only appointed the Distributed Energy Resource Management System (DERMS) vendor after significant DOE algorithmic development work had been undertaken by UoM. This created a project challenge for the DERMS vendor because it underwent a steep learning curve to incorporate the UoM algorithm into its own product.

Project EDGE touches many parts of the DNSP environment and organisation, as well as increased inter-company relationships which requires the various parties to collaborate, coordinate, and agree on solution design (technology and operation). While this has been a significant challenge for the project, it has been well managed through the partnering arrangements in the trial and the design processes that were implemented, both within the AusNet organisation and between the various entities.

Lessons learned

- Parallel development right from the start, with strong coordination, is likely to provide a smoother and more efficient implementation in future projects.
- The key insight from this experience is that implementing a DERMS and integrating it with the existing enterprise technology and operational ecosystem in a limited trial context is difficult – implementing it in a broader industry operational environment in the future will be much more challenging.

6.3.4 Resourcing movement

Projects that have a multi-year duration incur increased personnel movement risk. This has been a challenge for AusNet to manage in the trial. A compounding factor is that suitably experienced technical resources in this space are scarce. The AusNet team experienced multiple changes in the project management, systems architecture, and engineering areas with varying impacts on the project. Fortunately, these impacts have been reasonably mitigated through management actions, however it is an ongoing challenge in the current volatile market for these skill sets.

Lessons learned

- DNSPs will need to consider whether their workforce has the required skillset to facilitate DSO functions.

6.4 How AusNet interacts with the EDGE DER Marketplace

Integrating DER into the network is a key priority for AusNet. Over the last 10 years there have been numerous innovation initiatives to support increasing levels of customer DER connecting to the network and to develop related operational capability.

Over 20% of customers connected to AusNet's electricity distribution network have installed solar PV systems. Many parts of the network are now 'running backwards' during times of peak solar generation, meaning export from customer owned solar is exceeding demand for electricity during those periods. Available network 'static' solar PV hosting capacity (that is, the static export limit set by the DNSP across its network) is being consumed, to the extent that typically more than one in twenty new residential solar connection applications are constrained in their ability to export their generated energy to the grid.

In this context, AusNet developed a DER Roadmap in 2019 (recently updated in 2021) which included a capability model. The roadmap also set out key projects and activities to evolve its practices to be a customer centric DER-enabled network – a transformed network, which is enabled for, and enriched by DER, for the collective benefit of all connected customers. Project EDGE is a flagship project within the DER roadmap, as is the Flexible PV Exports initiative in which AusNet has partnered with SA Power Networks in another ARENA-funded project[50].

AusNet's approach with these roadmap projects is to consolidate and integrate the technology solutions so that the development of capability is efficient and aligned. To this end, the Project EDGE technology solution incorporates the opportunity to operationalise flexible PV export connections and to support business-as-usual demand management needs. In parallel, some of the Intellectual Property (IP) developed in the Flexible PV Exports project for the determination of dynamic export limits is being used in Project EDGE as a part of one of the DOE options being tested.

AusNet's experience and insights on the evolution from the current DNSP role into the DSO role is discussed in Section 6.3.

6.4.1 Wholesale integration

AusNet's primary interaction with the DER Marketplace as part the wholesale integration function is to communicate DOEs to AEMO and aggregators. As the DOE models progress in the simplicity-efficiency trade-off, AusNet's activities within the DOE communication interaction activity increase.

[50] At https://arena.gov.au/projects/sa-power-networks-flexible-exports-for-solar-pv-trial/

The progression of this interaction is summarised in Table 3 below at a high-level only. Models tested subsequent to the Advanced DOE Model will be desktop studies.

Table 3 AusNet's interactions with the DER Marketplace through the wholesale integration function

Progression model	Interaction with AEMO	Interaction with aggregators
Basic DOEs marketplace	AusNet calculates and sends a copy of the DOE to AEMO (for visibility).	AusNet calculates and sends the DOE to aggregators via the DER Marketplace.
Advanced DOEs Model	Same as above but in closer to real time.	
Grouped DOEs Model	Additional interactions	
	AusNet receives the NMI level dispatch plan calculated by aggregators via AEMO to facilitate the DOE update.	
	AusNet sends the re-calculated DOE to AEMO.	AusNet sends the re-calculated DOE to aggregators.
	AusNet receives aggregator dispatch instructions (for visibility).	

6.4.2 Local Services Exchange

AusNet has a higher volume of interactions with the DER Marketplace, specifically with aggregators, through the LSE function. AusNet communicates the need for local network support services based on a review of forecast network operating conditions that identifies peak demand management needs. AusNet then reviews local bi-directional offers made by aggregators to identify the offer/s that represent the best value while considering impacts on voltage regulation and selects the offer/s to deliver the required service and enters into an agreement with the relevant aggregator. Table 4 shows a high-level summary of interaction activities as part of the LSE function.

Table 4 AusNet's interactions with the DER Marketplace through the Local Services Exchange function

Scenario	Interaction with LSE platform	Interaction with aggregators
Forecast peak demand at 'feeder X'	AusNet posts the service need to market, including the details for the particular need such as location and duration.	AusNet reviews local bi-directional offer/s received from aggregators.
	AusNet sets the dispatch trigger for service delivery.	AusNet enters into an agreement for service delivery and with re-defined terms with the aggregator whose offers it has identified as representing the best value.
	AusNet records verification outcome in in LSE platform.	AusNet sends the arming signal to the aggregator.
	AusNet records a settlement or clawback in the LSE platform.	AusNet sends dispatch instruction to the aggregator.
		AusNet receives operational data for servicey delivery from the aggregator.

6.5 Design and technology

This section provides more detail on the design and technology elements AusNet considered, including DOE allocation objective functions and calculations, and the development of LSE service definitions and characteristics.

6.5.1 DOE allocation objective function, calculation and forecasting

Integration of large-scale DER into the grid could be enabled through the development and sharing of DOEs that establish the technical limits of a local network area. Based on AusNet's (and other DNSPs') experience, network impacts of DER are primarily related to voltage non-compliance and asset rating violation. These impacts are generally felt locally before manifesting themselves in upstream HV distribution networks. Power quality data from AusNet's fleet of smart meters provide further evidence to support this view.

DOEs are the limits an electricity customer can import and export to the grid and are currently set through a regulatory process and through connection agreements between a DNSP and customers. Current DOEs are generally static at conservative levels across the network to account for worst case scenario conditions. This means they are fixed regardless of the local network area capacity at a given time. Meanwhile, DOEs mean the limits can vary over time and location which can enable increased levels of exports from customers' DER since they consider hosting capacity on the local network at a point in time.

There are multiple options relating to the allocation objective function at which DOEs could be applied, ranging from all customers on the network being allocated the same capacity through to individual customers receiving different capacity allocation that could be different to the allocation given to their neighbour. Project EDGE is testing the latter approach of DOEs developed at a site (NMI) level. This allocation objective function has the potential to enable maximum opportunity for DER assets to participate in a DER Marketplace because the level of customer DER access to available network operational capacity is more reflective of the point at which the DER is connected to the network. Additionally, the widespread availability of smart meter analogue measurements in Victoria enable a more accurate assessment of power quality conditions in the LV networks.

There are various approaches to develop NMI level DOEs. The chosen approach is based on establishing a network model representing the active DERs and their immediate surrounds and using well-proven load flow techniques to calculate the voltages and currents in the network. The operating DOE represents the maximum import and export conditions at the site that satisfy voltage and thermal constraints.

Project EDGE has adopted the following approach to modelling LV DOEs:

- For active DER connected to a LV network supplied from a 2- or 3-phase HV network, the network model starts at the LV terminals of the distribution transformer.
- For active DER connected to a LV network supplied from Single-Wire-Earth-Return (SWER) HV network, the network model starts at the 12.7 kilovolts (kV) terminal of the SWER isolation transformer.
- Network topology and electrical data are extracted from AusNet's Geographical Information System.
- Phase connection, active and reactive power of customers are derived from smart meter data.

- Reference grid supply voltage for the network model is taken from transformer monitor measurements, or derived measurements from smart meters located at, or close to, the transformer (DER supplied from 2 or 3-phase HV network) or Automatic Circuit Recloser (ACR) immediately downstream of the SWER isolation transformer (DER in SWER network).

The different approach taken for DER in SWER networks is based on efficiency considerations. A typical SWER distribution transformer supplies only 1 to 4 customers and it would be very expensive to fit a transformer monitor to provide the reference voltage source. Setting up the network model to begin further upstream at the isolation transformer terminal provides a ready voltage reference source from the SWER ACR and eliminates the need to install a transformer monitor.

6.5.1.1 Calculation

DOE algorithms to calculate day-ahead export and import limits for customers supplied by 3-phase and SWER networks have been developed by UoM. UoM has also performed the associated network modelling and validation work for a group of initial test sites located in the north-east of Victoria. The initial DOE comprises active power only at the net NMI level. These DOE algorithms are currently progressing through design and implementation by AusNet's implementation partner, Opus One Solutions, within the procured DERMS solution. The function to produce a DOE is operational. Further developments of the DOE algorithms to incorporate reactive power and near-real-time (nRT) operation and enable additional functionality are being progressed and will be reported in later stages of Project EDGE.

Parallel to this implementation work, AusNet's digital team are working with the project team to separately establish a tool to work with the network model-based algorithms, such as those produced by UoM, as well as other non-network model-based algorithms through desktop simulations (i.e. outside of the DERMS solution). These simulations will enable AusNet to determine the most appropriate algorithms and test cases for DOE field trials within the DERMS solution.

The field trials that are expected to run from May 2022 until March 2023, will also include the trialling of economically optimised DOEs that are published with a frequency corresponding to the intra-day update of power quality data from the smart meter fleet. Refer to Appendix 1 for an illustration of the UoM day-ahead and nRT DOE architecture.

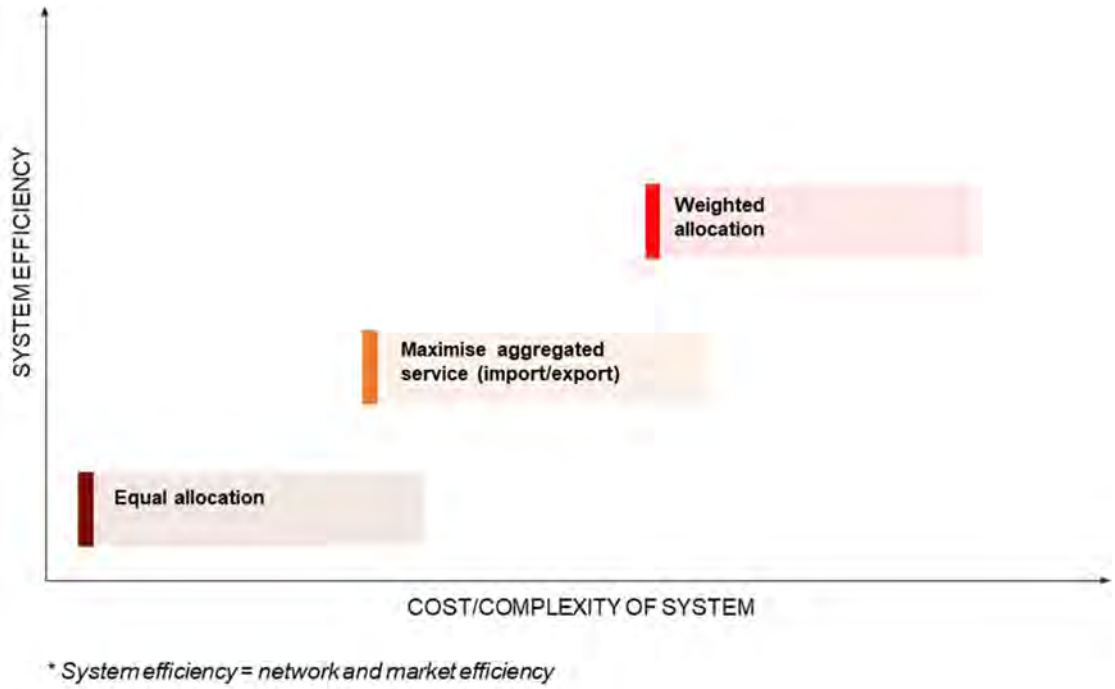
6.5.1.2 Objective functions and allocation options

The DOE implementation process includes the development of the objective function of the calculation. Three objective functions have been incorporated into the current design:

- Equal allocation.
- Maximise service (import/export).
- Weighted allocation.

These objective functions will be used within the field trials to test and identify the most optimal trade-off between complexity and market efficiency. The weighted allocation objective function for instance is hypothesised to increase market efficiency by 'weighting' the allocation of import and export capacity towards more economically competitive DER. However, the weighted allocation objective function is projected to involve considerable complexity and cost to operationalise. Therefore, the cost may not be worth the benefit, particularly when the costs associated with scale are considered. Figure 15 shows the efficiency and complexity and cost progression and trade-off.

Figure 15 The efficiency-complexity progression of the DOE allocation options



Refer to Appendix 2 for the UoM designed objective functions of allocation options.

6.5.1.3 Forecasting

Another consideration is the timeframe for DOE intervals and their recalculation frequency. This could range from 5-minute to 30-minute or hourly intervals, issued a day-ahead or adjusted in real time. More dynamic intervals are ideal because it has the potential to provide real-time solutions for DSOs, however, it is likely to incur higher operational costs. Project EDGE is testing day-ahead and intra-day DOEs. The calculation of day-ahead and intra-day DOEs requires forecasting of Head-of-Feeder (HoF) voltages and passive loads. From the data analysed so far in Project EDGE, this is one of the most significant challenges because of the variability and unpredictability of the customer loads. Various forecasting techniques are being tested, including Machine Learning (ML) approaches. At this stage of the project it is too early to provide analysis on the merits of the different forecasting techniques and will be revisited in future reports.

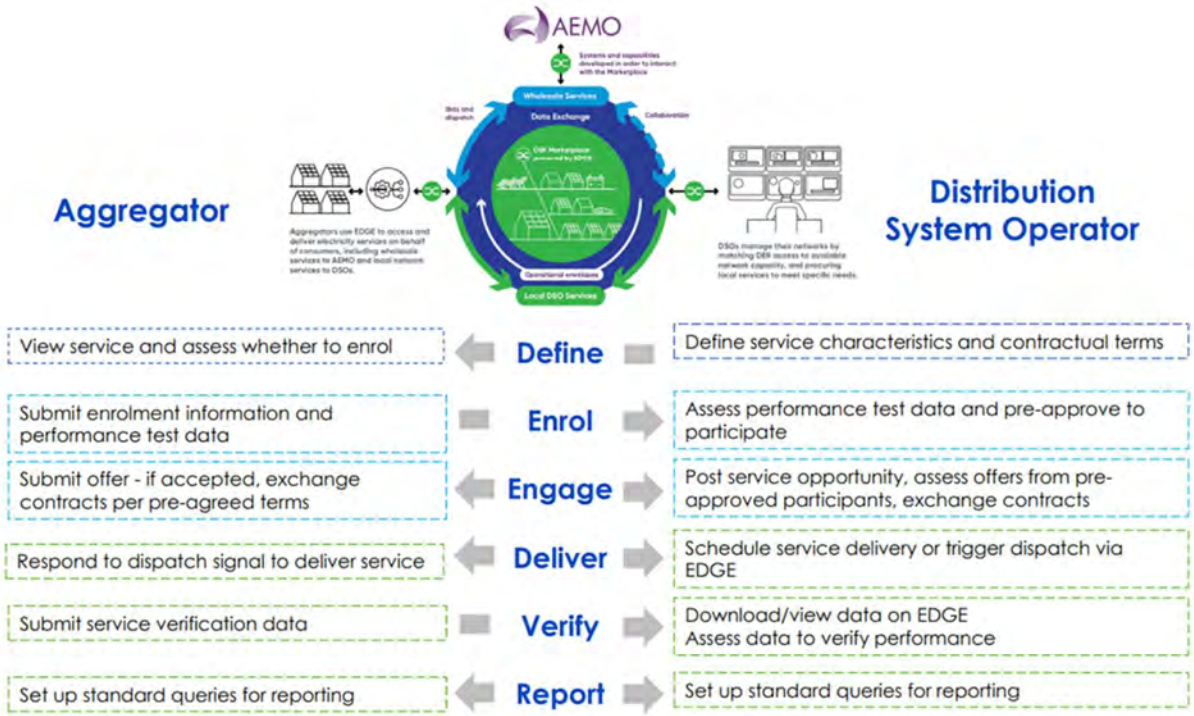
6.5.2 Local (network) services

The trading of local network services between the DSO and aggregators within the Project EDGE DER Marketplace will be facilitated by the LSE function. Though still in high-level design, the lifecycle, service definitions and service characteristics have been established. The initial focus of local services will be the management of load demand and voltage compliance, assisting the DSO to defer capital or operational expenditure and improve customer service. The network model set up by UoM will be used to determine the quantum and effectiveness of various local services.

6.5.2.1 LSE Lifecycle

Figure 16 shows the key phases of the LSE lifecycle.

Figure 16 The LSE lifecycle and the role of the DSO and aggregator



Refer to Appendix 3 for further information on the LSE lifecycle stages, as well as associated roles and an example lifecycle process for the Demand High Firmness standard service.

6.5.2.2 LSE standard service definitions

There are currently six LSE standard services anticipated for the market:

- Demand High Firmness.
- Demand Medium Firmness.
- Demand Low Firmness.
- Voltage High Firmness.
- Voltage Medium Firmness.
- Voltage Low Firmness.

Refer to Appendix 4 for further information relating to LSE service definitions including classifications and proposed service characteristics.

6.5.3 Aggregator and customer management

AusNet has set export limits for solar and battery connection depending on the size of the DER system and the local network area constraints. To maximise the testing opportunities for DOEs, AusNet is dynamically increasing the export limit for customers participating in Project EDGE.

AusNet's business rules for solar and battery connections up to 30 kW stipulate that:

- A maximum of 10 kW total inverter (solar and battery) capacity is installable per phase, and 5 kW export is allowed per phase (3.5 kW for SWER).
- Up to a maximum of 30 kW total inverter capacity and 15 kW export is allowed across 3 phases.
- Installations in specific constrained areas of the network may be subject to additional export limitations.

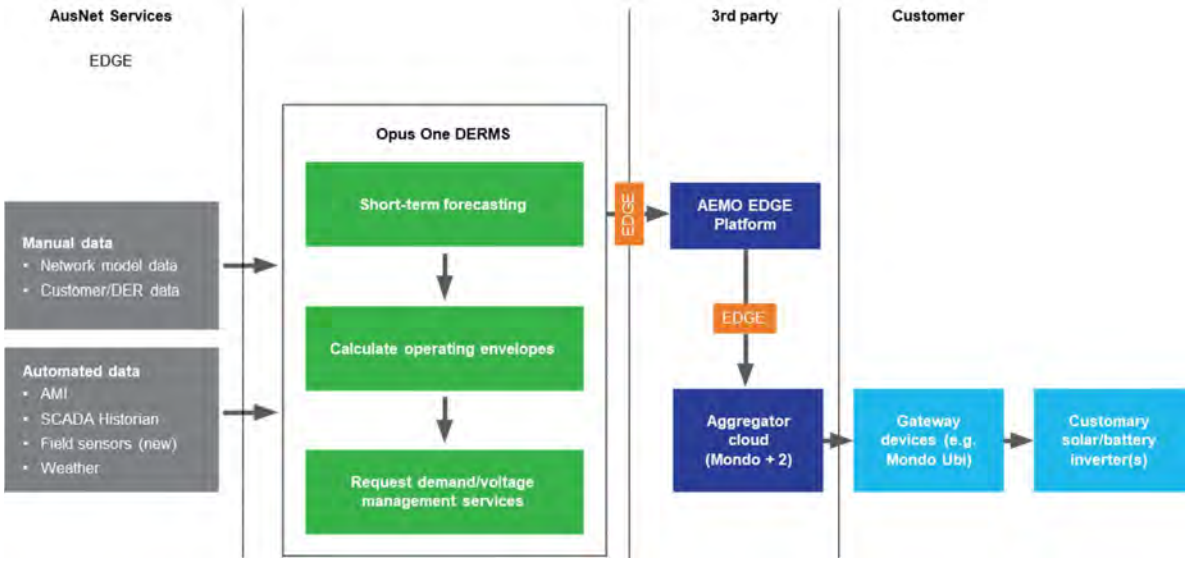
For the first phase of Project EDGE, AusNet will dynamically increase the export limit of participating customers up to a maximum of 10kW per phase via a flexible connection agreement. This increase will be applicable until Project EDGE finishes or the customer ceases participating in the project, at which point the original export limit may be reinstated. However, AusNet anticipates a gradual transition for Project EDGE customers onto a more permanent flexible connection agreement. This is currently in early stages of development.

A registration process for aggregators and participating active customers will be developed as more aggregators sign up to Project EDGE.

6.5.4 Technology and infrastructure

To support the data exchange in the Project EDGE DER Marketplace, AusNet needed to implement a DERMS to manage the data and coordinate the aggregated DER within the trial. DERMS require integration of various other business systems to provide full functionality, including the SCADA system. Figure 17 shows the interaction of the data received by AusNet from Project EDGE with the DERMS, and its interaction with the project data exchange platform and aggregators. As more aggregators sign up to Project EDGE, a registration process for aggregators and participating active customers will be developed. The DSO perspective on the data exchange approach is discussed further in Chapter 4.

Figure 17 The interaction between AusNet's DERMS and data exchange with Project EDGE



7 Aggregator

7.1 Mondo's role in Project EDGE

Mondo is the principal aggregator partner for Project EDGE and has extensive experience providing aggregation services for DER customers, particularly in the Hume region of Victoria. Mondo has an internally designed and developed DER management and aggregation platform, underpinned by the proprietary 'Ubi' behind the meter monitoring and control unit. This platform is being augmented for Project EDGE. Refer to Section 3.1.3 for a discussion on Mondo's roles and responsibilities in Project EDGE.

Guided by its functions and responsibilities within the project, Mondo has also set out the following objectives for its part in Project EDGE:

- Augment the existing Mondo DER platform capability to support improved forecasting, optimised bidding and disaggregated DER dispatch to deliver enhanced DER services to AEMO, DNSPs and NEM participants via the Project EDGE market platform.
- Develop a deep understanding of customer perceptions and expectations to design DER product offerings that can be economically bid as standardised aggregated services into the NEM and for use by DNSPs.
- Build relationships across AEMO, industry regulators, retailers, DNSPs, customer representatives and other industry partners to work together on a future DER Marketplace.

7.2 Preliminary findings

To date, Mondo's findings relate to:

- Developing customer knowledge and acquisition methodologies.
- Designing offers that meet specific demographic needs.
- Developing an aggregation platform that supports coordination with market participants to structure and submit market bids into the wholesale market, develop forecasts, manage dispatch and compliance of DER to dispatch instructions.
- Assigning incentives and managing customer expectations.

Developing customer knowledge and acquisition methodologies

Customer perception and understanding of aggregated DER varies extensively and often their understanding of retail prices, tariffs and electricity market mechanisms is limited. Successful customer acquisition requires extensive engagement and building of trust within target communities. Simplified messaging, ongoing customer education and continuous communication and support play a significant part in meeting acquisition goals. Additionally, evidence suggests that engaging at a local level through installers and community groups active in the renewables and sustainability space is highly effective.

Developing customer offers that meet specific demographic needs

Designing aggregation products and services that appeal to the various residential and Commercial and Industrial (C&I) customer categories is difficult. The customer insights study commissioned as part of Project EDGE is intended to provide a better understanding of the needs, aspirations, and motivations of existing and intending DER customers. A 'one size fits all' approach is unlikely to work well. Additionally, in the context of Project EDGE, the absence of a settlement mechanism for DER services (within the trial) requires the aggregator to identify appropriate financial incentives to encourage customers to sign up. These amounts need to be included in the aggregator budget for Project EDGE.

Developing an aggregation platform

Design and development of an aggregation platform that provides a good experience for DER customers while also supporting the complex forecasting, bidding and disaggregated dispatch functionality required to participate in a two-sided DER market is a non-trivial exercise. Even where an aggregator has an existing platform, Mondo's experience is that significant effort is required to implement the market functions and central integration to the market operator platform.

Assignment of incentives for the trial

The Project EDGE scope only includes simulated settlement activities for DER services, and therefore no real payments from the wholesale market or the DNSP would be available to compensate end customers for the use of their solar and battery installations. Accordingly, all incentives to participate in Project EDGE provided to Mondo's end customers were funded by Mondo from its project budget.

Mondo developed an incentive structure that broadly allocated the payments across the following categories:

- Residential vs C&I.
- Initial vs ongoing/usage based.

The intent of this allocation approach was to ensure that incentive payments were sufficiently aligned to the expectations of the customer type while providing trial customers the ability to opt out of participation if their individual circumstances changed.

Managing customer expectations

A recurring theme from prospective end customers considering or undertaking participation in Project EDGE with Mondo as their aggregator is the importance of clear and timely communication on matters relating to how their DER devices will be used and how their needs are prioritised. For example, customers expect their aggregator will inform them in advance of any activities that require exercising control over their DER devices. Similarly, customers expect their aggregator will confirm consent where the customers have stated expectations. For example, not discharging their batteries below a certain predefined threshold (for instance, they might want to retain capacity in case of a critical weather event) or limiting the charge and discharge cycles that their battery assets undergo over a period. Mondo has also had to provide assurances the use of the customer's DER device in the trial will not leave the customer financially worse-off (e.g. any loss of feed-in-tariffs would be equalled or exceeded by the financial incentives received by the customer).

Any real market implementation of the arrangements trialled within Project EDGE will need to balance the individual expectations of the DER owners with the market expectations from the use of that DER to provide services.

Customer support

Even before the commencement of Project EDGE, Mondo has been supporting customers through its DER platform and Ubi behind the meter device. Mondo has established customer support processes and the ability to remotely assist customers with issues related to the aggregation systems. These frameworks will continue to be used to support customers who are participating in Project EDGE.

7.2.1 Lessons learned and challenges

In the period since the inception of Project EDGE, several challenges have led to emergence of key learnings in relation to acquiring and supporting aggregation customers and their DER devices and systems.

- Customer engagement and acquisition.
  - The cost of battery and solar generation equipment is a significant hurdle for prospective customers, and the value customers perceive from the use of DER is not necessarily financial. The utility that arises from supporting sustainability, renewables and energy resilience within their local community are all important drivers. Often, a customer's priority is to maximise self-consumption of solar generation and that is what they expect aggregators to prioritise.
  - Engaging with prospective customers and obtaining agreement to use their DER for aggregated energy services, requires aggregators to build trust at a community level and engage with the financial and non-financial drivers that motivate DER owners. Energy literacy is another significant challenge that influences customer acquisition. Often, customers are not aware of how the current electricity market arrangements work. For example, it is not clear to them why feed-in-tariffs are different to the price they pay to purchase the same amount of power from their energy retailer.
  - Much of Mondo's success in signing up customers for Project EDGE builds on its previous engagements in the Hume region. The ability to scale customer acquisition across broader areas up to, and including, the full NEM may be subject to the ability of respective aggregators to do the same.
- Aggregation systems development.
  - For Project EDGE, Mondo has worked closely with AEMO and AusNet to design and develop information exchange protocols which are fit-for-purpose and scalable. Without agreed standards for DER information exchange, the cost of aggregating a diversity of solar and battery installations will severely impact the overall value of a DER market. See Section 2.3.1 for a discussion on common communication protocols, and Chapter 4. For example, the IEEE 2030.5 protocol was used as a template to exchange DOE settings with the DNSP. However, the specific requirements of Project EDGE have meant the program has needed to adapt and create a semi-bespoke version of that protocol for the trial. Increased standardisation of these protocols is a critical factor in the success of a future live DER Marketplace.
  - To participate in a DER Marketplace, aggregators would need to develop complex capabilities to enable some of its core functions. The aggregator is required to develop and implement

sophisticated capacity forecasting algorithms so that an aggregated bid/offer for DER services may be developed and submitted a day in advance to the market. Similarly, the ability to receive dispatch instructions from the market operator and disaggregate it to NMI level instructions across the fleet of DER is another complex functionality the aggregator is required to develop.

  - In summary, much of Mondo's success in developing the necessary systems for the trial is due to leveraging prior investments in its aggregation platform technologies and the close working arrangements with AEMO and AusNet in the development of Project EDGE functionality and information exchange protocols. These are factors to consider carefully when looking to include and support additional aggregators into Project EDGE.

- DER installation and configuration.
  - The initial cohort of DER customers signed up by Mondo to participate in Project EDGE consists mostly of residential customers with pre-existing solar and battery installations. However, timely and reliable installation services is key for the remaining customers expected to participate. Mondo has accordingly been engaging closely with installation partners within the communities it is targeting for customer acquisition. Installers can often prove to be key in the aggregator's ability to reach out, educate and engage with prospective customers looking to install DER.

7.3 How Mondo interacts with the EDGE DER Marketplace

Mondo plays an active role in the DER Marketplace and interacts heavily both with AusNet as the DSO, and AEMO as the Market and System Operator through the wholesale integration and LSE functions.

7.3.1 Wholesale integration

The extent of Mondo's interactions is influenced by the efficiency-complexity progression model applied. Certain high-level interaction activities continue through each progression model, however, the details of the activities within these interactions change as the complexity progresses. The progression of these interactions is summarised in Table 5 below at a high-level only.

Table 5 Mondo's interactions with the DER Marketplace through the wholesale integration function

Progression model	Interaction with AEMO	Interaction with DSO
Basic DOEs marketplace	Mondo reviews available capacity in its portfolio and creates or updates and submits regional bi-directional offer/s for the wholesale energy spot market considering the DOE communicated by AusNet.	Mondo receives the DOE from AusNet.
	Mondo receives dispatch instructions from AEMO.	Mondo performs local dispatch for network services to AusNet according to the dispatch instructions it receives from AEMO.
	Mondo provides AEMO operational data for dispatch verification.	
	If Mondo does not meet its dispatch target compliance, it will engage with AEMO as it	If Mondo does not meet its DOE compliance, it will engage with

Progression model	Interaction with AEMO	Interaction with DSO
	takes appropriate action for the non-compliance.	AusNet as it takes appropriate action for the non-compliance.
Advanced DOEs Model	Same as above but in closer to real time	
Grouped DOEs Model	Additional interactions	
	Mondo provides operational data and dispatched NMI list to AEMO for dispatch verification.	Mondo receives re-calculated DOE from AusNet.

7.3.2 Local Services Exchange

Mondo has a higher volume of interactions with AusNet through the LSE function of the DER Marketplace. Mondo responds to the DSO's communicated need for local network support services based on an assessment of the stacked value. Where Mondo determines there is greater stacked value from a local bi-directional offer than a wholesale energy bi-directional offer, it will commit available capacity from its DER portfolio to the network need communicated by AusNet. If AusNet selects the relevant offer/s from Mondo, the two parties will enter into an agreement with pre-defined terms on the LSE service delivery. Table 6 shows a high-level summary of interaction activities as part of the LSE function.

Table 6 Mondo's interactions with the DER Marketplace through the Local Services Exchange function

Scenario	Interaction with LSE platform	Interaction with DSO
Forecast peak demand at 'feeder X'	Mondo reviews network support service need posted by AusNet.	Mondo enters into an agreement with AusNet on the offer/s selected by the DSO.
	Mondo submits a local bi-directional offer.	Mondo receives an arming signal from AusNet before service delivery.
		Mondo receives dispatch instruction from AusNet at the time service delivery starts.
		Mondo sends AusNet operational data for the service delivery.

7.4 Design and technology

Over the last five years Mondo has made significant investments in developing the Mondo platform, and the Ubi monitoring and control device. These investments have resulted in a platform that is able to monitor, control and orchestrate a range of DER devices alongside other devices such as hot water, air conditioners and EV chargers.

Project EDGE will require Mondo to extend its platform to deliver marketplace integration for wholesale and network services. At the completion of the project, the new platform capability and aggregated DER resources will be offered to market and network suppliers as part of an aggregation offering.

Project EDGE is aligned with Mondo's vision to be a leader in creating an efficient, secure, sustainable and integrated new energy future across Australia.

7.4.1 Aggregation services

Mondo has identified several aggregation service categories to trial and assess for commercial viability (not all of which are within the scope of the Project EDGE trial). These are summarised in Table 7 and Table 8.

Table 7 Potential wholesale services provided by DER

Wholesale Services Customer Value	Technical Service	Description	Project EDGE scope
Wholesale risk management	Generation Demand management Forward contracts	DER deployed into the wholesale energy market to manage the risk of high prices resulting from high demand. This may help market participants satisfy their prudential requirements (with AEMO), their Retailer Reliability Obligations (with the Australian Energy Regulator (AER)) and internal risk management requirements.	**Partially within scope:** Dispatch of DER to manage high demand is within scope. However, their impact on prudential requirements and reliability obligations is not within scope.
Wholesale energy savings	Generation Demand management Forward contracts	DER can be bid in and dispatched to the electricity market by the aggregators for market payments.	**Partially within scope:** Mondo's DER portfolio is testing wholesale market participation by bidding into the EDGE DER Marketplace and receiving dispatch signals from AEMO.
End-use customer/supplier retention and acquisition	Supplier bill reduction Supplier payments	Well-designed aggregation platforms can provide highly valued DER monitoring and control capabilities to customers.	**Within scope:** Mondo is testing an aggregation platform.
Reliability and Emergency Reserve Trader (RERT)	Demand response Generation	Aggregators may be able to utilise the EDGE platform to supply 'off-market' demand response and generation to cover forecast capacity shortfalls through a tender process.	**Not within scope.** The extent to which DER can be used to provide demand response services is through the local (network) services exchange function.
Wholesale Demand Response Mechanism (WDRM)	Demand response Generation	Aggregators may be able to offer demand response into the wholesale spot market.	**Not within scope:** Although Mondo's portfolio will test responses to high price events, it is not participating in WDRM.
Frequency Control Ancillary Services (FCAS) (recently enabled)	Demand response Generation	FCAS markets allow AEMO to keep the grid in balance over timescales of less than 5 minutes. AEMO has developed a technical specification for the delivery of contingency FCAS from aggregated DER.	**Not within scope:** The EDGE DER Marketplace will not test/facilitate FCAS bidding, but aggregators participating in EDGE may also participate in FCAS markets with a Victorian DER portfolio if they wish.
Fast Frequency Response (FFR) (being developed)	Demand response Generation	FFR provides frequency control services within milliseconds and is particularly valuable in response to unplanned system events. This service is currently being designed by AEMO.	**Not within scope:** FFR is not yet operational.

Table 8 Potential network services provided by DER

Network Services Customer Value	Technical Service	Description	Project EDGE scope
Avoided Transmission Use of System (TUOS) charges	Generation Demand management	DNSPs pay TUOS to TNSPs as payment for the use of the transmission system. These payments are based on the maximum amount of energy DNSPs draw from transmission networks at any one time. DER provides an alternative source of energy that does not require the use of the transmission system.	**Not within scope:** While this would be an extension of benefits provides by the LSE function it is not being specifically tested in the project.
Avoided Network Augmentation	Generation Demand management Voltage regulation	Aggregated DER can supply a range of services which allow NSPs to defer or avoid capital expenditure on the network. The value of this deferral is defined through a Regulatory Investment Test (RIT).	**Within scope:** This will be tested through the LSE function and other research activities in the Research Plan
Meeting Regulatory Obligations and Improving end-use customer outcomes	Voltage regulation Dynamic export limiting Congestion relief	NSPs have several performance obligations. Many of these requirements can be addressed through aggregated DER services.	**Within scope:** Utilisation of DER to enable DOEs and identified network needs such as congestion relief will be tested in the project.
Distribution Congestion Relief	Application and management of flexible export limits	The ability for aggregators to apply dynamically varying export limits to its fleet of active DER customers can be offered to relieve distribution network constraints to allow greater end-use customer demand to be supplied, and more generation to be supplied to the wholesale energy market.	**Within scope:** Utilisation of DER to enable DOEs and identified network needs such as congestion relief will be tested in the project.
Avoided penalty payments to the Regulator via the Service Target Performance Incentive Scheme (STPIS)	Generation Demand management Voltage regulation	The STPIS allows the regulator to penalise or reward DNSPs based on how reliable their networks are. Aggregated DER can be deployed to avoid unplanned outages on the distribution network, improving network reliability.	**Within scope:** This will be tested through the LSE function and other research activities in the Research Plan
Transmission Congestion Relief	Demand response Generation	Relieving transmission network constraints to allow more generation to be dispatched, and more end-use customer demand to be supplied.	**Not within scope:** The project is testing the impacts of DER on the distribution network technical limits. Impacts on the transmission network are not in scope.

7.4.2 Customer acquisition

For Project EDGE, Mondo is targeting a mix of residential and C&I customers across the Hume area to achieve the necessary levels of aggregated scheduled (dispatchable) generation and storage capacity.

As part of the customer acquisition work required for Project EDGE, Mondo is responsible for:

- A customer education program focused on educating customers about the benefits they can access by participating in the DER Marketplace.
- Development of business models aimed at mapping out the different revenue streams and allocation across the supply chain – customer, aggregator (Mondo), other market participants.
- Development of customer incentives.

This work will be informed by the research questions, hypotheses and test cases and activities set out in the Project EDGE Research Plan[51]. Most relevant is the research question testing how the DER Marketplace can be designed to enable simple aggregator and customer experiences, deliver the needs of customers, and improve social licence for active DER participation.

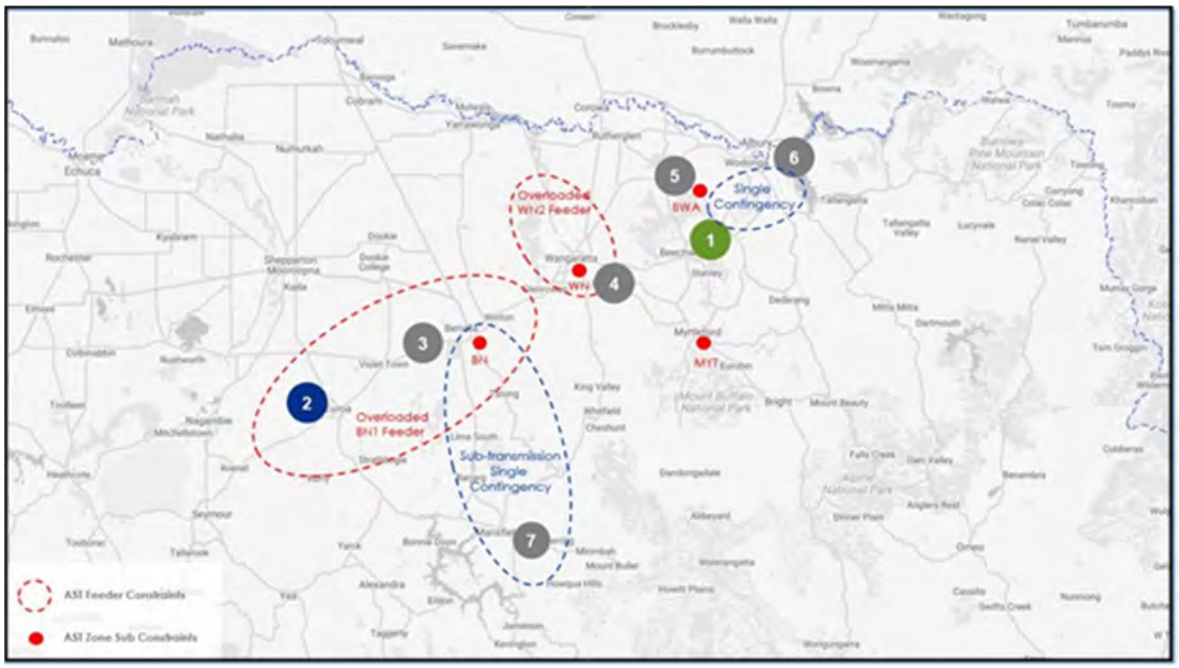
The customer number targets for Project EDGE will increase through the course of the trial as shown in Table 9. Figure 18 shows an overview of the sites selected for customer acquisition.

Table 9 Customer acquisition target progression for Project EDGE

Trial Phase	Target region (Mondo)	Acquisition objectives	Minimum customer numbers
Initial	1. Yackandandah and Beechworth	Initial residential customers on single low voltage networks, including instances of: • High penetration of solar PV and battery on single low voltage network. • SWER network customers.	38 residential
Expanded	2. Euroa	Additional customers across multiple low voltage networks within Euroa, including: • C&I customers. • Residential customers. • Grid-connected batteries (optional).	14 C&I 20 residential
Scaled	3. Benalla and Violet Town 4. Wangaratta 5. Barnawartha 6. Wodonga 7. Mansfield	Additional C&I and residential supplier base across Hume: • C&I customers across 5 identified hubs within Hume. • Residential customers across Hume.	30 C&I 200 to 1,000 residential

[51] At https://aemo.com.au/-/media/files/initiatives/der/2022/master-research-plan-edge.pdf?la=en

Figure 18 Site selection overview – Hume focus areas and their associated project phase



The Hume region was initially selected for Project EDGE due to Mondo's previous success with DER customers in the area. Prior to the commencement of Project EDGE, Mondo already had several customers with Ubi installations, supported by Mondo and its aggregation platform. The communities in the Hume area have proven to be particularly active and supportive of sustainability and de-carbonisation initiatives. Furthermore, the specific sites selected within the Hume region were identified as areas where the network is more constrained. Therefore, the value of using locally aggregated DER services to manage the constraints via market mechanisms would be greater. However, Project EDGE is not limited to customers in the Hume area. Mondo and the additional aggregators expected to participate in the latter phases of Project EDGE may choose to seek customers across other regions of the AusNet distribution area.

As noted in Section 7.2, Project EDGE will not demonstrate real settlement processes. Accordingly, Mondo has needed to establish a customer incentivisation methodology based on a payment model that is not directly linked to the value of the services that Project EDGE will test. Instead, Mondo's incentives are based on compensating participants for the right to control their PV and battery systems at various pre-agreed points during the trial. Mondo has also sought to assure its customers that every effort will be made to ensure that participation in the trial will not result in customers being materially worse-off either through missed feed-in-tariffs or loss of access to their battery capacities.

7.4.3 Aggregation platform

Mondo commenced Project EDGE with a mature aggregation platform developed internally and deployed to several hundred sites. The aggregation platform consists of an 'Ubi' behind the meter intelligent monitoring and control device and a cloud-based aggregation platform. It provides DER customers a high-quality user interface they can use to monitor and control their solar and battery system alongside grid energy flows and significant loads. Participation in Project EDGE required the development of new features to deliver the functions designed and tested in Project EDGE, including

the ability to interface with the DER Marketplace platform for bids and offers, deliver network services and comply with DOEs.

The aggregation platform is the single largest cost for Mondo to act as a Project EDGE aggregator. Within the Project EDGE DER Marketplace, the platform will:

- Enable monitoring, coordination, bidding and dispatch of DER into the LSE.
- Deliver fundamental features that are key to customer acquisition and retention within the trial.

Table 10 lists the core platform functions required by an aggregation platform to effectively perform as an aggregator in Project EDGE. In addition to the functions listed in Table 10, the platform has performance monitoring functionality, but it does not have payments or settlements functionality. For Project EDGE, these elements are handled separately without automation because payments to end DER customers are not directly linked to performance.

Table 10 Core aggregator platform functions for Project EDGE

EDGE Function	Details
Forecasting	• Aggregated and NMI net meter forecast. • Aggregated and NMI solar forecast. • Aggregated and NMI battery forecast. • Aggregated and NMI demand forecast.
DOEs	• Ability to receive DOE and send it through to the end devices. • Ability to keep customers within defined dynamic import and export limits.
Wholesale bidding and dispatch	• Determine the best time to buy and sell energy based on wholesale price and availability. • Determine prices at which Mondo is prepared to buy or sell energy. • Structure a bid file and submit to AEMO that includes quantities in price bands. • Receive dispatch signal and deliver wholesale services. • Validate service delivery with AEMO.
Local network services	• Provision of energy and voltage services to a network. • Trial services that range from forecastable (the aggregator has time to plan for delivering the response) to immediate (help network solve an immediate issue). • Allow customers more access to available capacity by offsetting voltage impacts with reactive power.
Disaggregation	• Taking an AEMO dispatch signal, disaggregate the dispatch target and recruit individual customers to deliver the required service. • Monitor and adjust the fleet to continuously meet the dispatch target. • Determine how much reserve capacity is required to deliver firm services.
Valuing services	• Determine the price at which the aggregator is prepared to sell services at a particular time (offer). • Determine the cost at which the aggregator is prepared to purchase energy at a particular time (bid). • Calculate base costs associated with battery operation and ensure the customer always benefits.
Customer visibility and preferences	Explore what level of notification customers want when delivering services from their DER: • Pre-warning.

EDGE Function	Details
	• Notified during event. • Post event log of events. • Explore customer preferences for participating in markets: • Opt in/out. • Exclusion days/times. • Number of events per year. • Value based.
Market linkages	Identify trends and patterns in services, including: • Do high price events happen at the same time as a need for a network service? • Are the highest value services at times when customers have sufficient energy or potential in DER to deliver? • Do DOEs work with or against market services?
Battery performance	Develop a comprehensive understanding of battery performance for service delivery: • How reliably can they deliver? • How long can they deliver? • How often are they available to deliver a service? • What times of day/days of week are they available? • What is the impact of extreme heat/cold?
Service patterns	Develop a comprehensive understanding of exactly how often and when services will be required: • All day and every day or only when prices are extreme? • How often does a network require local services? • How often do customers get curtailed by DOE? • How often do customers get access to greater envelopes?

Development of these functions will be informed by several research questions and activities set out in the Research Plan[52]. Particularly those concerned with identifying the most efficient and scalable way to exchange data among industry actors, and how the DER Marketplace can facilitate:

- Activation of DER to respond to wholesale signal, operate within network limits and progress to participation in wholesale dispatch over time.
- Efficient and scalable provision of local network support services from DER so that network efficiency benefits are realised for all customers.

[52] At https://aemo.com.au/-/media/files/initiatives/der/2022/master-research-plan-edge.pdf?la=en

8 Cost benefit analysis approach

This chapter provides an interim update on the CBA as it develops through Project EDGE. Continued development of the scenarios, specific assumptions and quantification methodologies will be included in subsequent interim reports and form the basis for the continued stakeholder engagement process.

A CBA is one of the key Project EDGE deliverables. In August 2021, AEMO engaged Deloitte Access Economics (Deloitte) to carry out this analysis to determine whether the establishment and operation of a DER Marketplace would be in the long-term interests of electricity consumers in the NEM. The CBA will quantify the net economic benefits a DER Marketplace could provide to consumers and form one of the key inputs into any electricity rule changes and regulatory proposals that may be required in the future to scale the preferred solution.

Deloitte has partnered with Energeia for this deliverable. To complete this CBA, Deloitte and Energeia will utilise:

- A base case which represents a conceivable approach to market operations and DER management informed by the AEMO Draft 2022 ISP Step Change scenario. Additional assumptions and specific rule changes will be developed through internal and external stakeholder consultation.
- Development of multiple scenarios involving a DER Marketplace allowing aggregators to utilise consumer DER to participate in a centralised dispatch system over the same outlook period. In addition to considering the wholesale integration of DER, additional scenarios will cover data exchange functions and local services exchange functions and variation in DER penetration.

The costs and benefits will be drawn from Energeia's whole-of-system modelling platform, which includes a Wholesale Market Simulator (wSIM) that models wholesale market conditions and a Utility Simulator (uSIM) that models consumer behaviour. Additionally, a bespoke model will be computed to assess adjacent value potential associated with recent changes to market settlement intervals (to 5-minute intervals) and contingency frequency response ancillary services (the latter being outside the scope of concurrent experimental work within the project scope).

Scenarios are utilised to test the value of the Project EDGE Marketplace within future market environments with varying key parameters (such as economic growth, DER uptake and demand).

This chapter provides background on the CBA methodology Deloitte and Energeia will use to quantify the net economic benefits of Project EDGE. The next steps include:

- Provision of initial modelling results in the milestones and lessons learned reports.
- Further modelling results in the milestones and lessons learned reports.
- A final CBA report, lessons learned and a chapter in the Public Project Report by mid-2023.

Deloitte is in the process of internal finalisation of scenarios, baseline and associated assumptions required for the CBA modelling. Next steps will involve:

- Stakeholder engagement on scenarios and baseline assumptions.
- Commencement of techno-economic modelling (TEM) following confirmation of baseline and scenarios.
- Project EDGE trial commencement and integration plan for outputs feeding into the CBA.

An indicative schedule is provided in Figure 19, denoting key milestones and workstreams. Internal and external stakeholder engagement will ensure the assumptions and methodologies are reflective of both market understanding and the required level of robustness.

8.1 The purpose of the CBA

CBA is an appraisal technique used to quantify the net economic benefit delivered by a specific project based on the estimation in monetary terms of all costs incurred and benefits realised as a result of the project's implementation.

The purpose of this CBA is to identify and analyse whether the implementation of an operational DER Marketplace (after the proof-of-concept version is tested in Project EDGE) is in the long-term interests of consumers and under which conditions (for example, DER operation, penetration and customer demand). If it proves to be in the long-term interests of consumers of electricity in line with the NEO, the CBA will also assess under which scenarios adding more complexity and sophistication to the DER Marketplace may be justified. For example, how distribution network limits should be considered in wholesale dispatch and how DER participation in central dispatch should be progressively achieved.

The CBA methodology for Project EDGE has been developed with consideration to the most recent guidelines for undertaking CBA, including:

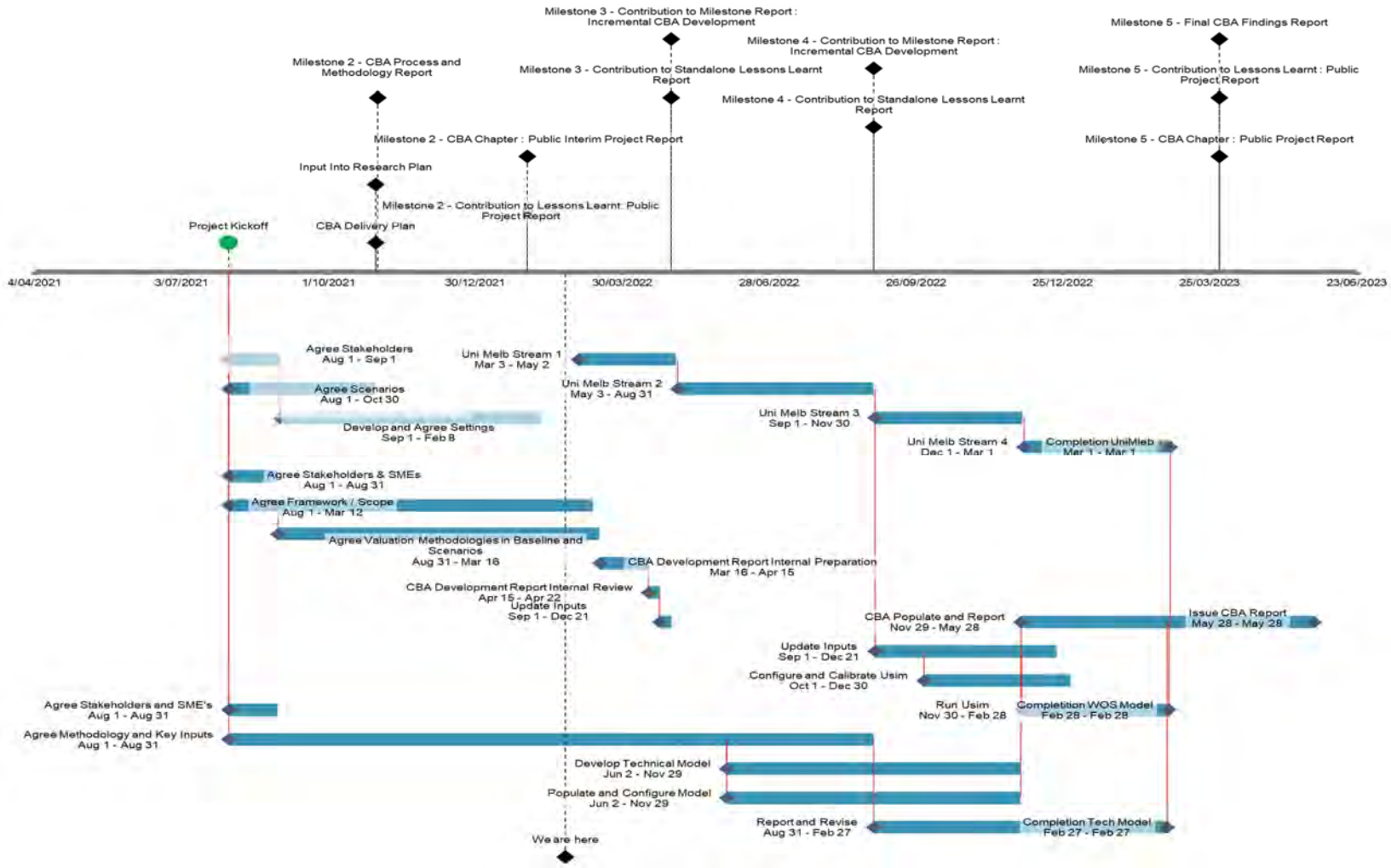
- Australian Energy Regulator (AER), Cost benefit analysis guidelines – guidelines to make the Integrated System Plan actionable (August 2020)[53].
- AER, Draft DER integration expenditure guidance note (July 2021)[54].
- Department of the Prime Minister and Cabinet, Guidance note on cost-benefit analysis (March 2020)[55].

[53] At https://www.aer.gov.au/system/files/AER%20-%20Cost%20benefit%20analysis%20guidelines%20-%2025%20August%202020.pdf

[54] At https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/assessing-distributed-energy-resources-integration-expenditure/draft-decision

[55] At https://obpr.pmc.gov.au/resources/guidance-assessing-impacts/cost-benefit-analysis

Figure 19 Indicative schedule and milestones



8.2 Stakeholder engagement

Stakeholder consultation is an important activity for any project. For a project like Project EDGE, where energy market participants and peak bodies are actively engaged in thought leadership around the broader energy transformation, engagement is key to their inclusion on the journey.

Specifically for the Project EDGE CBA, stakeholder consultation will include static and dynamic activities designed to capture energy market activities, thinking and strategic trend setting, to review, categorise and action thinking on relevant energy market topics. Static review of materials such as working papers, reports and stakeholder comments to published work will be considered, as will interactive consultation such as regular public workshops and one-on-one stakeholder meetings with targeted stakeholders such as the AEMC, ESB and AER (see Figure 20).

Discussions with these parties and other key energy market contributors will ensure the assumptions that underpin the CBA are refined in line with stakeholder views and reflect the latest datapoints. The list of key stakeholders will be reviewed and expanded, as needed, pending project evolution and emerging requirements. Ensuring the CBA methodology is robust and sensible relative to stakeholder expectations is a priority, as is building a body of evidence to support what final assumptions are used in the CBA. This will also ensure credible and defensible results are derived.

8.3 CBA and techno-economic modelling interaction

The TEM provides outputs under varying scenarios which feed into the cost benefit assessment of the CBA. Costs or benefits not directly captured by the TEM but material to testing of the research hypotheses will be further investigated and methods determined to quantify the impact and feed into the CBA. Figure 21 illustrates the relationship between the CBA framework and the TEM.

Figure 20 Stakeholder timeline

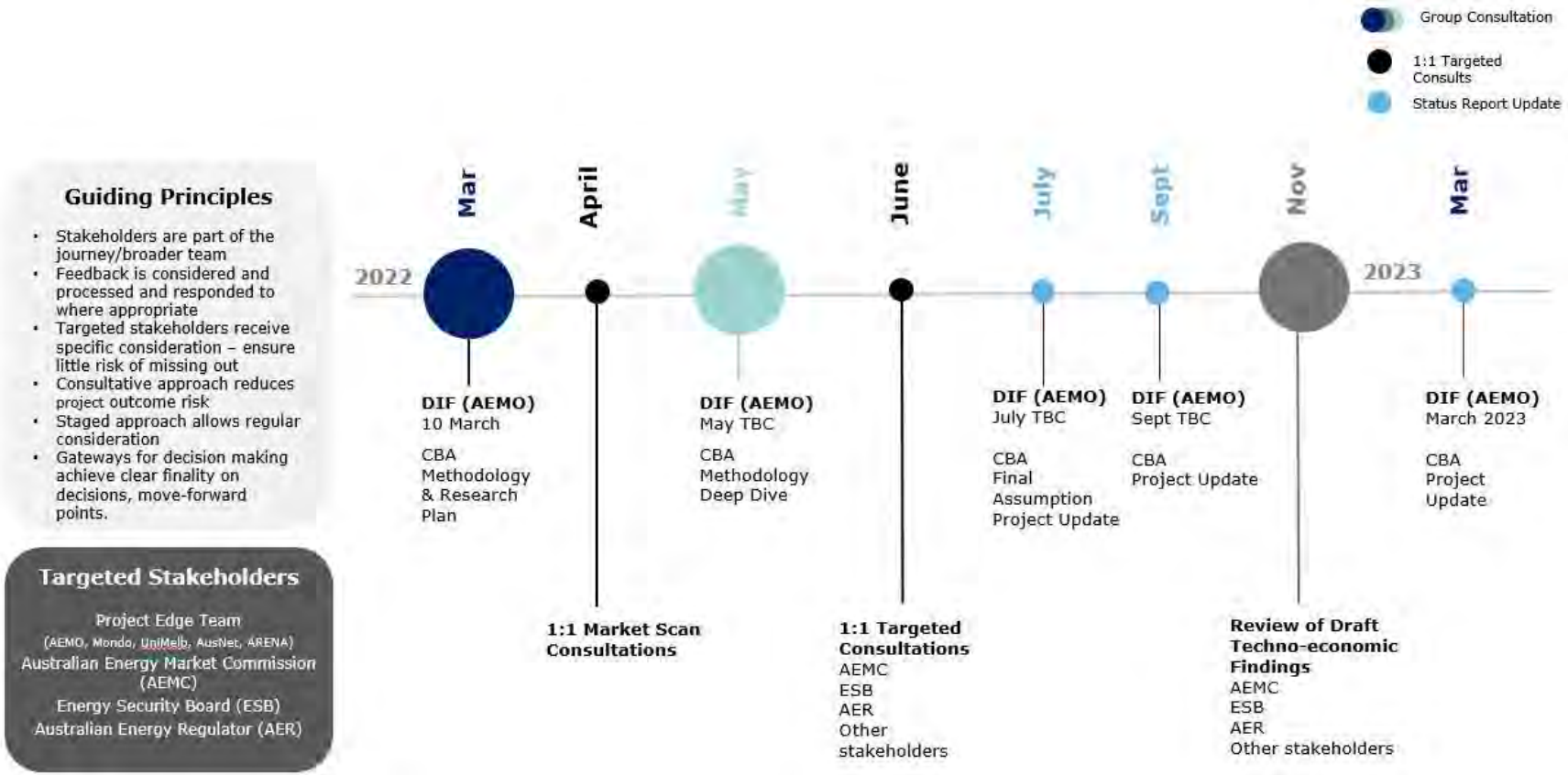
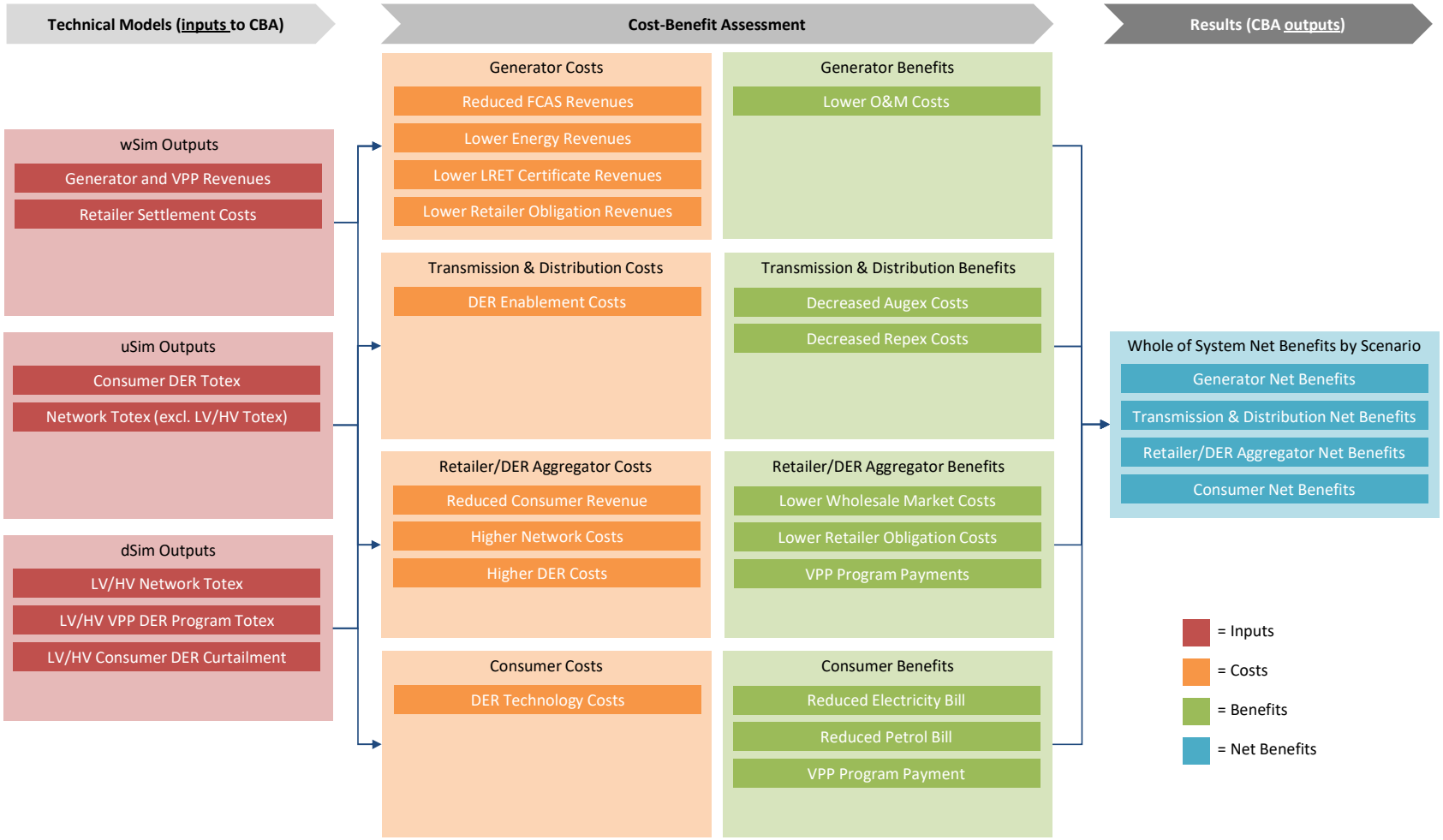


Figure 21 CBA framework and relationship to technical modelling



8.4 CBA research questions

UoM developed a Project EDGE Research Plan[56] that outlines priority research questions and associated hypotheses of the Project. Outcomes from the CBA will inform and test the following research questions and associated hypotheses.[57]

8.4.1 Research Question 1

Research question 1 tests *how the DER Marketplace can be designed to enable simple customer experiences, deliver the needs of customers and improve social license for active DER participation*.

Table 11 below summarises the research hypotheses and the outputs of the CBA framework used to validate them.

Table 11 Relevant hypothesis to research question 1

	Hypothesis (Hp)	CBA assessment method
Hp.C	Enabling aggregators to deliver multiple services whilst minimising market complexity can enable them to provide valuable and simple offers to customers to activate their DER.	Determine the cost and benefits of the aggregators to participate in simple and sophisticated markets. The cash flow of the aggregator should consider revenue from markets and cost of dispatching customers' assets and controls required to participate in the market. This will inform on the business case of the aggregator to participate and perform this function (in comparison to AEMO) in a market with given complexity.

8.4.2 Research Question 2

Research question 2 tests *if the DER Marketplace promotes efficient investment in, and efficient operation and use of, electricity services for the long-term interests of consumers*.

Table 12 below summarises the research hypotheses and the outputs of the CBA framework used to validate them.

Table 12 Relevant hypothesis to research question 2

	Hypothesis (Hp)	CBA assessment method
Hp.A	A DER Marketplace can deliver net positive economic impacts for consumers, particularly if started simply and developed progressively as DER penetration increases.	Assessment of whole of system NPV under simple arrangements and extrapolated out based on DER forecasts.
Hp.B	DER delivery of local services enables DNSPs to defer investments and efficiently manage network reliability and ensure efficient long-term outcomes for consumers.	Assessment of the impacts to the DNSP procurement of local services (and therefore deferment of network capex/repex) through standardisation of the definition and trade of local network services. It is estimated that networks could pay DER customers over $2.5 billion per annum for grid support services by 2050[58].

[56] At https://aemo.com.au/-/media/files/initiatives/der/2022/master-research-plan-edge.pdf?la=en

[57] Additional research questions and associated hypotheses will be tested via other activities such as literature reviews, customer engagement, technical analysis and field trials.

[58] At https://www.energynetworks.com.au/resources/reports/electricity-network-transformation-roadmap-final-report/

	Hypothesis (Hp)	CBA assessment method
Hp.C	A data hub model reduces cost and complexity of data exchange and provides an economically efficient and scalable approach for DER Marketplace.	Assessment of the difference in costs providing both wholesale (AEMO) and local (DNSP + aggregator) service types to operate the data hub concept compared to direct point to point integration. The distinction is driven by the costs to integrate between all parties, the scalability of the data exchange and any efficiencies that can be unlocked (e.g. retailers sending zero export limit requests to Inverter Original Equipment Manufacturer (OEMs)). This hypothesis will be tested early in the project to inform industry discussion.

8.4.3 Research Question 3

Research question 3 tests *how does operating envelope design impact the efficient allocation of network capacity while enabling the provision of wholesale energy and local network service*.

Table 13 below summarises the research hypotheses and the outputs of the CBA framework used to validate them.

Table 13 Relevant hypothesis to research question 3

	Hypothesis (Hp)	CBA assessment method
Hp.A	The design of the operating envelopes has a material impact on the network operation and efficient provision of wholesale energy and local network services.	Assessment of the value unlocked due to DOE with different spatial and temporal resolutions, network capacity allocation objective function, features such as active power only or both active and reactive power and complexity.
Hp.C	It is possible to increase efficiency (aligning to the NEO) of operating envelope design and implementation as DER penetration increases.	Cost benefit analysis to compute economic value unlocked due to different designs of operating envelopes against the cost of sophistication.

8.4.4 Research Question 4

Research question 4 tests *how the DER Marketplace can facilitate efficient activation of DER to respond to wholesale price signals, operate within network limits and progress to participation in wholesale dispatch over time*.

Table 14 below summarises the research hypotheses and the outputs of the CBA framework used to validate them.

Table 14 Relevant hypothesis to research question 4

	Hypothesis	CBA assessment method
Hp.C	The aggregator should be responsible for ensuring DER can effectively provide stacked delivery of wholesale energy and local network services simultaneously instead of the market operator co-optimising these services.	Cost benefit analysis that includes stacked delivery of wholesale energy and local network services considering: a) the aggregator being responsible for ensuring DER effectively and simultaneously provide the stacked services; and b) market operator co-optimising these services. This test can be done for different volumes of DER and for different combination of services. If for a given DER penetration and set of services the economic efficiency achieved in the case of aggregators being responsible to provide stacked delivery of service is equal or higher than in the case of the market operator co-optimising, the aggregator can be responsible of stacking delivery of services.

8.4.5 Research Question 5

Research question 5 tests *how can the DER Marketplace facilitate efficient and scalable provision of local network support services from DER so that network efficiency benefits are realised for all customers*.

Table 15 below summarises the research hypotheses and the outputs of the CBA framework used to validate them.

Table 15 Relevant hypothesis to research question 5

	Hypothesis	CBA assessment method
Hp.A	Network reliability can be managed through the provision of local network services from customer-owned assets.	A cost-benefit analysis on DNSP activities extrapolated from the trial data (field tests plus desktop analysis) and business-as-usual (BAU) DNSP activities, e.g. how much effort is involved for DNSP to enable LSE, required behavioural changes, accuracy of forecasting and valuing the network needs, efficiency of effecting the various LSE transactions, compared with network alternatives. The results of this test will show the economic efficiency of implementing the proposed local network services for DNSPs.

8.4.6 Research Question 7[59]

Research question 7 considers *how could DNSP investment to develop DSO capabilities improve the economic efficiency of the DER Marketplace*.

Table 16 below summarises the research hypotheses and the outputs of the CBA framework used to validate them.

[59] Research question 6 considers *what is the most efficient and scalable way to exchange data between industry actors, considering privacy and cyber security, to benefit all consumers?* Research question 2, hypothesis C, addresses this question and hypothesises a data hub model reduces cost and complexity of data exchange and provides an economically efficient and scalable approach for a DER Marketplace. The CBA assessment method is outlined in Table 12.

Table 16 Relevant hypothesis to research question 7

	Hypothesis	CBA assessment method
Hp. A	There is an optimal combination of DNSP investment in network and DER based non-network solutions which results in higher economic efficiency and improved operation of the DER Marketplace as DER penetrations and density increases.	Cost-benefit analysis to determine possible incentives for DNSP investment, (a) based on the data from a combination of a desktop studies and field tests in the trial to assess the techno-economic benefits of investing in the network to align the active management of the distribution network (e.g. voltage levels, configuration etc.) with the prevailing wholesale energy market conditions, to actively increase hosting capacity and DER participation in the wholesale energy market and (b) from data gathered from local service provision tests and DNSP capex and opex to determine what financial benefits arise from DNSP investment for the aggregator and what role the aggregator can have to incentivise DNSP investment. This test case will provide insights on the incentives that promote DNSP investment that enables higher DER market participation, and the costs and benefits that arise from these investments for the different stakeholders.

8.5 CBA framework

8.5.1 CBA assumptions

Table 17 CBA assumptions

Parameter	Input
Referent groups	Customers, aggregators, retailers, networks (DSO), AEMO
Period of analysis	20 years
Base year	FY23
Discount rate (lower bound)[60]	4.83%[61] (subject to change).
Sensitivity analysis[62]	To be determined based on the identification of risks during stakeholder engagement

8.5.2 Base case

The base case is a BAU approach to market operations and DER management (for example bilateral contracts for DER-based network support services that are invisible to the market via many point-to-point integrations). This is essentially maintaining the current wholesale market and dispatch engine as the singular wholesale marketplace for electricity. The activities included within the base case are those which are ongoing, economically prudent and those which would occur in the absence of a credible option.

[60] As per AER CBA guidelines the lower boundary discount rate should be the regulated cost of capital, based on the AER's most recent regulatory determination.

[61] AER (April 2021), Final Decision AusNet Service Distribution Determination 2021-2026. At https://www.aer.gov.au/system/files/AER%20-%20Final%20decision%20-%20AusNet%20Services%20distribution%20determination%202021%E2%80%9326%20-%20Overview%20-%20April%202021.pdf

[62] Required to test how robust the outputs are to different input assumptions.

The timeframe over which market interactions are assessed also important in quantifying the costs and benefits of the base case as a BAU approach to market operations and DER integration over the outlook period. Therefore, all activities that are required to maintain the status quo will be included in associated base case costs and benefits.

The specifications of the base case will be determined during internal workshops and involve participation from key external stakeholders. The definition will account for the following key considerations:

- Level of DER uptake.
- Upcoming market reforms.
- Integration of DER (both active and passive DER).
- Data exchange and local services exchange models.

Key considerations and inclusions within the base case definition and quantification:

- Operational, maintenance and minor capital expenditure required to allow BAU to be maintained as effectively as possible, for as long as possible.
- 'Risk costs' consistent with BAU risk mitigation and management activities.
- Credible BAU expenditure relating to the deteriorating asset to manage safety risk, environmental risk and equipment protection to the extent this expenditure meets legal obligations or is consistent with efficient industry practice.

8.5.3 Project case (Project EDGE)

The project case represents the project definition of the trial as the facilitation of a DER Marketplace that enables the defined three core functions:

1. Wholesale integration of DER – DER fleets must be dispatched as if they are participating in existing wholesale markets (energy and ancillary services), while considering distribution network limits in the dispatch process. Specifically, the project case will facilitate aggregators operating as if they were a type of scheduled resource in an off-market setting, by submitting bi-directional offers and receiving/acting on dispatch instructions from AEMO.
4. Data exchange – set of capabilities and functions developed to facilitate streamlined data exchange between AEMO, DNSPs and aggregators. Specifically, the project case will facilitate the operation of a data hub concept.
5. Local Services Exchange – an interface to facilitate visible, scalable and competitive trade of local DER services that enables DNSPs to manage local power security and reliability and enables aggregators to stack local and wholesale value streams efficiently. To test scalability in line with the NEO, LSE interactions will be facilitated via the data hub.

The project case will also define the roles of AEMO, DSO and aggregator within the CBA as follows:

- AEMO – wholesale market and transmission system operator that receives outputs and offers from the DER Marketplace. AEMO will have the systems and capabilities developed to interact with the DER Marketplace.

- DSO – The DSO is the role of the DNSP to dynamically manage capacity and operate its network by matching DER access to available network capacity and procuring local services to meet specific needs[63].
- Aggregator – Aggregators are participants who use EDGE to access and deliver electricity services on behalf of consumers, including wholesale services to AEMO and local network services to the DSO.

While Project EDGE is a trial, the CBA will analyse the impacts of the DER Marketplace being operationalised over the course of a baseline year (FY23). This will then be used to extrapolate results for a period of 20 years.

Field tests are being used primarily to check and demonstrate the functionality of various operating envelope, market, demand and generation configurations. Technical trials will be performed as part of the field trials and the data from the trials will be assessed against the estimated DOE results. The findings from this comparative analysis will feed into the DOE techno-economic modelling and the CBA. In some cases, further evaluation from CBA simulation is required to best inform the equitability of a given configuration or scenario; in others, preliminary research already indicated an advantageous situation relative to a given research hypothesis.

8.5.4 Costs

Cost inputs for the CBA are those relevant to an in-production DER marketplace. Costs included are reflective of costs incurred across the market by all relevant stakeholders.

Specific costs relating to the development and deployment of the DER Marketplace from a technology perspective will be provided by the project's technology subcontractors, Opus One, PXiSE and Energy Web as a starting point. These costs will represent the costs of implementing the simple marketplace, including those such as developing and hosting the data exchange and bids and dispatch system. Appropriate cost assumptions will be developed by complementing technology.

Internal and external stakeholder engagement will also be utilised to provide advice on costs such as aggregator costs (for example costs to serve), compliance and governance costs associated with the project. Expected cost categories are provided in Table 18 below.

Table 18 Project case expected cost categories

Cost Category	Description	Cost source
Technology costs (with regards to market operator and DNSP systems)	Costs incurred in developing and deploying the required technology, including relevant system integration costs. In addition, a variable cost (above project costs) will need to be considered to assess the change in technology costs as the complexity and size of the marketplace changes.	• AEMO technology subcontractor (PXiSE and Energy Web). • AusNet's technology subcontractor (Opus One). • Other DNSPs. • Desktop research.

[63] During the trial the capability of the DSO to align network operational practices (e.g. voltage management) to benefit the wholesale energy market will be explored

Cost Category	Description	Cost source
Operating and maintenance costs (with regards to the platform and also technology costs within the DNSP environment related to the project)	Opex associated with maintenance and operation of the project and also system integration. Operating and maintenance costs include ongoing costs applicable to all stakeholders including the DNSP, Market Operator, aggregator and customers.	• Technology subcontractor (PXiSE and Energy Web). • AusNet's technology subcontractor (Opus One). • Other DNSPs. • Desktop research.
Cost of complying with laws, regulations and administration	Costs to register DER Marketplace and administration costs applied to participants.	• Stakeholder engagement and desktop research.
Retailer/aggregator costs ('cost to serve')	Costs applied to the retailer or aggregator as a result of participating in the DER Marketplace or as a result of the DER Marketplace existing (e.g. technology costs). This would include customer management costs, marketing costs, hardship provisions (to be built in as a contingency).	• Stakeholder and Project EDGE participant engagement and desktop research. • Technology subcontractor.
Electricity network costs	Costs associated with DER enablement (increased DER connecting to the network).	Output of technical models; particularly with respect to infrastructure costs associated with managing additional (passive DER) peaking network capacity.
DER technology costs	Costs borne by consumers to purchase and install DERs required to participate in the DER Marketplace (solar PV system, battery storage system, appliances, etc). These will vary based on the underlying scenario assumptions and will be specific to relevant marketplace, DER trajectory, etc.	Stakeholder engagement and desktop research. Some consideration will be required of the role of incentives (as some DER classes have established trajectories e.g. PV, other classes may be party to significant market distortion in the future, e.g. EVs).
Generator costs	Costs or cost transfers away from generators in relation to their revenues. This may include reduced FCAS revenues, lower energy revenues, lower LRET certificate revenues, lower retailer obligation revenues.	Output of technical models.

8.5.5 Benefits

When deciding which benefits to measure, it is important to first consider the objective of Project EDGE. The objective is associated with target outcomes, which will in turn be expected to generate certain benefits. Deloitte will work with the stakeholders to identify the key expected benefits that result from the target outcomes of the project.

Expected benefit categories are provided in Table 19 below.

Table 19 Project case expected benefit categories

Benefit	Benefit category	Description
Planned and unplanned outage support	Customers	DER can supply individual customers and/or local networks after network faults, where it can be islanded, reducing unserved energy and outage duration. • Planned outages - service to provide capacity (for 1-6-week timeframes) to address planned outages. • Unplanned outages – used reactively with minimal notice to provide capacity to enable the network to be reconfigured.
Reduction in DER curtailment	Customers	Increased value generation for customers through increased use of their assets.
Reduced electricity bills	Customers	Assessing the impact of increased DER uptake on the bill stack (wholesale, network and retail) and benefits from potential use of AEMO settlement to reduce settlement risks.
Increased DER hosting capacity	Networks	Increased network hosting capacity of DER by maximising participation in energy, ancillary and network service markets, while ensuring the secure technical limits of the electricity networks are not breached.
Capex (augex and repex) deferral	Networks	The AER's draft DER integration expenditure guidance notes that increased procurement of services from DER as non-network solutions may lead to avoided/deferred distribution augmentation. If it increases the amount of load supplied from within distribution networks and may reduce peak demand at upstream network assets[64]. Increased procurement of services from DER as non-network solutions may lead to avoided/deferred distribution augmentation.
Avoided replacement/asset derating	Networks	Increased DER capacity can lower the average load on network assets, enabling asset deratings and when replacement is required, smaller, cheaper assets can be installed. This benefit is enabled when: • peak demand[65] is not growing over time at the relevant network asset • peak demand coincides with times when DER exports are enabled • network asset longevity can be improved by reducing loads[66].
Reduced line losses	Networks	Increases in DER generation may result in avoided transmission and distribution losses. DER generation can supply loads within the distribution network, reducing the supply from centralised generators connected to distribution networks by transmission lines, which avoids energy being lost to heat when transported over transmission lines. It can also reduce the distance the energy travels across the distribution network compared to centralised generators, which reduces the amount of energy lost to heat when transported over distribution lines[67].

[64] At https://www.aer.gov.au/system/files/Draft%20DER%20integration%20expenditure%20guidance%20note%20%286%20July%29.pdf, page 15

[65] Increased DER generation can alleviate peak generation through time-shifting load capabilities

[66] At https://www.aer.gov.au/system/files/Draft%20DER%20integration%20expenditure%20guidance%20note%20%286%20July%29.pdf, page 18

[67] At https://www.aer.gov.au/system/files/Draft%20DER%20integration%20expenditure%20guidance%20note%20%286%20July%29.pdf, page 18

Benefit	Benefit category	Description
Voltage management	Networks	• Reactive power service to manage over/under voltage excursions. • Alleviate binding voltage constrains and unlock further export/ import capacity.
Benefits of greater visibility, predictability, and control for AEMO and network operators	Networks / AEMO	More accurate system forecasts and improved situational awareness leading to lower overall system need/cost for ancillary services (regulation FCAS) and better real-time decision making in control rooms (fewer interventions/procurement of RERT through better understanding of reserve situation).
Reduced CO2 emissions (quantity of CO2 emissions)[68]	All	Increased penetration of DER may also help reduce overall CO2 emissions of the NEM, by displacing other more emissions-intensive generation.

8.5.6 Limitations

The following limitations regarding the CBA have been noted and efforts will be made throughout the development of the project and CBA to lessen the impact of the limitations on the robustness of the outcomes[69]. This intends to ensure the outputs are at a suitable level of accuracy for the intended use.

- While it is intended that real data from Project EDGE practical trials should be used within and to further inform desktop analyses, the statistical relevance of real-world data concerning Project EDGE participants to wider populations is not defined. A structural, statistical assessment of the limitations of the sample subset should be undertaken once relevant customers are acquired.
- Explicit costs are limited to data provided by project participants and are not representative of all go-to-market possibilities associated with DERMs and adjacent platform provisioning. Subject to constraints and validation.
- Benefits from ancillary services participation are computed on statistical assumptions based on average power flows and permitted power envelopes throughout a dispatch window. As the project's practical studies do not include ancillary services participation or simulation, no practical data is able to be provided within methods experimentally evaluated in the project scope. However, if appropriate historical data is made available from other projects it will be used.
- Modifications to wholesale and network costs are computed per year of simulated observances, other update rates may be negotiated.
- The performance simulation of variable export limits and market opportunities are dependent in part on performance characteristics of the practical implementation of these systems and cannot be computed in a generalised sense. Simulation characteristics should reflect practical system characteristics, with an appropriate schedule of relevant factors communicated from practical implementation(s) to the CBA and agreed openly.

[68] No financial value will be attributed to this benefit based on AER guidance that environmental benefits may only be quantified if there is an identifiable tax, levy or other payment associated with environmental or health costs which producers are required to pay or where jurisdictional legislation directs NSPs to consider the impact of these externalities and has provided a value that is to be used

[69] Limitations will be tested and refined during stakeholder consultation

- The accuracy of network performance simulation is dependent in part on the quality of data concerning load characteristics and network design as communicated from practical implementation(s) to the CBA and agreed openly.
- Load and generation shapes and other incumbent, adjacent data sources concern 30-minute time intervals on which simulations are computed. No reliable means of up-sampling this data to 5-minute time intervals with predictable, acceptable accuracy exists in lieu of original data at 5-minute or lesser time intervals. A sample of individual cases within the network region simulated will be statistically examined in a subsequent simulation for value potential in a 5-minute market scenario, with any additional value created noted as potential value additional to that computed in core simulations underpinning the CBA.

It is anticipated that the impact of these limitations, in the context of a macro level CBA, have minimal impact on the robustness of comparison between scenarios. Sensitivity analysis will be performed to assess the validity of this assumption. Identified material impacts will be further investigated and resolved where possible.

8.6 CBA scenarios

Scenario analysis will be utilised as part of the CBA to test the value of the Project EDGE DER Marketplace within different future external market environments. By comparing one scenario to the next, the impacts of key changes can be quantified and related to changes in market operations. The first and last scenarios are used to bookend the analysis moving from a rudimentary operating envelope and market design to a sophisticated data hub and local services exchange. Incremental changes to operating envelope accuracy and the co-optimisation method allow testing of the impact of these changes to rates of DER participation, network investment and participant revenue streams.

The UoM's research work will inform scenario parameters, giving rise to a specific number of scenarios to simulate. At the time of writing a range of factors are being considered in scenario design, including factors around relevant active DER, passive DER and architecture feature availability and uptake.

It is stressed that simulation work as part of CBA efforts is not a digital twin per se but a modelled approach to capturing salient elements of the principles evaluated within the Project EDGE framework. Owing to both the limitations of the method and recent changes to market settlement intervals affecting available data useful towards NMI level modelling, it is not yet determined that the simulation method employed are sufficiently sensitive as to reliably reveal differences between every test suggested by the current test plan. Critically, the DOE algorithms forming a significant portion of the test plan are only recently becoming available for review, with some still in development. Work is ongoing to understand the best way to realise the intent of the CBA mission within the practical and computations test resources available.

8.6.1 Summary of the DOE/market arrangements scenario elements

- The co-optimisation model refers to whether just Virtual Power Plants (VPPs) or all active DER participate in the market (net pool vs. gross pool).
- DOE Optimisation Methodology refers to whether optimisation is carried out based on approximations or LV network data (costs vs. accuracy trade-off) the latter to be modelled by UoM.
- The Target Operating Model refers to the optimisation objective (pro-rata, maximise service value, minimise costs based on economic bids).

- VPP Standards and P2P/H&S Integration apply equally across all scenarios and assume the introduction of DER facilitative reforms slated in the ESB post 2025 NEM review.
- Data hub and Localised Service Exchange act together, assuming that a data exchange hub is a perquisite of the efficiently scalable trading platform.
  - Counterfactual to the Hub and LSE arrangement is the growth in VPPs with no coordination/standardisation of data and local services exchange, requiring aggregators to interact with DNSPs on a 1 to 1 basis across a variety of non-standard platforms and jurisdictions, with flexible exports occurring in 3-4yrs.

UoM will provide information in the format outlined in Table 20 to describe levels of curtailment at average DER generation levels. Numbers below are indicative and to be provided by modelling.

Table 20 Indicative DER constraints framework

	Avg. kW / Customer During Event (only PV and DR varies by ToU)						
	0	1	2	3	4	5	6
Thermal Constraint							
LV Transformer	0%	0%	40%	80%	85%	90%	95%
HV Feeder	0%	0%	0%	40%	80%	85%	90%
ZS	0%	0%	0%	0%	0%	40%	80%
Voltage Constraint							
LV Transformer	0%	10%	80%	90%	95%	98%	99%
HV Feeder	0%	0%	0%	0%	0%	0%	0%
ZS	0%	0%	0%	0%	0%	0%	0%

Working scenarios are presented in Figure 22, providing a framework for measurement of incremental benefit of the marketplace and varying rates of DER penetration, operating model and market participation. Lower and upper scenarios act as bookends as the market represented moves from rudimentary to one of increasing accuracy and sophistication. Underlying assumptions are to be further refined through internal and external engagement.

Figure 22 Comparison of key assumptions for the CBA

Scenario Element	Basecase 1	2	3	Low DER Scenario 4	5	Basecase 6	7	8	High DER Scenario 9	10
Load and DER Assumptions										
Customer and Energy Growth	AEMO Step Change					Renew / ECA High				
Solar Uptake										
Battery Uptake										
EV Uptake										
Heat Pump Water Heating Uptake										
VPP uptake										
DER Service Use Cases										
AEMO RERT Service	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
AEMO AS Service	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
AEMO Ramping Service	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
AEMO FCAS Service	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Retailer Capacity Service	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Retailer NEM Charges Service	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Retailer Network Charges Service	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Network TX Voltage Service	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
etwork TX Thermal Service (BSP/Terminal Station)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Network ZS Thermal Service	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Network HV Thermal Service	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Network HV Voltage Service	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Network LV Thermal Service	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Network LV Voltage Service	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
DOE / Market Arrangemets										
Constraint Optimization Frequency	Daily	Daily	Daily	intra-day TBC during stakeholder consultation (DNSPs and Reg)	intra-day TBC during stakeholder consultation (DNSPs and Reg)	Daily	Daily	Daily	intra-day TBC during stakeholder consultation (DNSPs and Reg)	intra-day TBC during stakeholder consultation (DNSPs and Reg)
Co-optimization Model	VPP Only	VPP Only	VPP Only	100%	100%	VPP Only	VPP Only	VPP Only	100%	100%
DOE Optimization Methodology	Approximatio	Approximatio	Approximatio	LV Data Driven	LV Data Driven	Approximatio	Approximatio	Approximatio	LV Data Driven	LV Data Driven
Target Operating Model (TOM)	Nameplate Pro-rata	Max Service Value	Max Service Value	Economic Optimisation	Economic Optimisation	Nameplate Pro-rata	Max Service Value	Max Service Value	Economic Optimisation	Economic Optimisation
VPP Standards and P2P/H&S Integration	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Data Hub			✓		✓			✓		✓
Local Services Exchange			✓		✓			✓		✓

AEMO's Step Change scenario was most recently provided in its Draft 2022 ISP, and its most recent load and DER assumptions are provided in an associated assumptions report and workbook[70]. This scenario involves a consistently fast-paced transition from fossil fuels to renewable energy resources in the NEM compared to AEMO's other ISP scenarios. Based on extensive consultation with industry stakeholders, AEMO treated this scenario in the Draft 2022 ISP as the one most likely to occur[71]. This CBA incorporates the load and DER assumptions for AEMO's Step Change scenario as its low DER scenario.

The Renew/Energy Consumers Australia (ECA) load and assumption figures come from Energeia's 2021 Renew DER Optimisation (Stage II) final report. The engagement received funding from ECA. Energeia was the technical consultant for this engagement and modelled its own Consumer High DER scenario as well as comparing the assumptions of this scenario with those of the AEMO ISP's Step Change scenario[72]. This CBA incorporates Energeia's Consumer High DER scenario from that project as the high DER scenario for load and DER assumptions.

The key differences in assumptions between the Project EDGE CBA's Low DER scenario based on AEMO's ISP and the High DER scenario from the Renew project are provided in Figures 23, 24 and 25. These comparisons were developed by Energeia for the 2021 Renew DER Optimisation (Stage II) final report. Notably, AEMO's Step Change scenario includes expected adoption rates of 49% for residential solar PV and 24% for residential battery storage systems by 2040, while Renew and Energeia forecast a 93% adoption rate of residential solar PV and a 90% uptake of residential battery storage systems by that time.

[70] At https://aemo.com.au/-/media/files/major-publications/isp/2021/2021-inputs-assumptions-and-scenarios-report.pdf?la=en; https://aemo.com.au/-/media/files/major-publications/isp/2021/2021-inputs-and-assumptions-workbook.xlsx?la=en

[71] At https://aemo.com.au/-/media/files/major-publications/isp/2022/draft-2022-integrated-system-plan.pdf?la=en, pages 27 and 29

[72] At https://energeia.com.au/wp-content/uploads/2022/02/Renew-DER-Optimisation-Final-Report-210930v2.pdf, pages 4 and 32

Figure 23 Comparison of load and DER assumptions incorporated into the Low DER scenario (AEMO Step Change) and High DER scenario (Consumer High DER)

	Scenario Name	
	AEMO Step Change	Consumer High DER
Key Scenario Drivers		
Distributed Technology Prices		
Solar PV	AEMO Step Change	Trend
Storage	AEMO Step Change	Trend
Distributed Technology Adoption Rates		
Solar PV	39% by 2030, 49% by 2040	90% by 2030, 93% by 2040
Storage	14% by 2030, 24% by 2040	80% by 2030, 90% by 2040
Distributed Technology Adoption Sizes		
Solar PV	AEMO Step Change	Economically Optimal
Storage	AEMO Step Change	Economically Optimal
Electrification Rates		
Buildings	80% by 2030, 90% by 2040	80% by 2030, 90% by 2040
Transportation	AEMO Step Change	AEMO Step Change
DER Management		
Water Heating	100%	100%
Vehicle Charging	100%	100%
Storage	100%	100%
Solar PV	100%	100%
National Electricity Market		
Fuel Prices	AEMO Step Change	AEMO Step Change
Technology Costs	AEMO Step Change	AEMO Step Change
Networks		
LRMC	Published	Estimated

Source: Energeia

Figure 24 Comparison of residential rooftop solar PV forecasts for both scenarios in MW

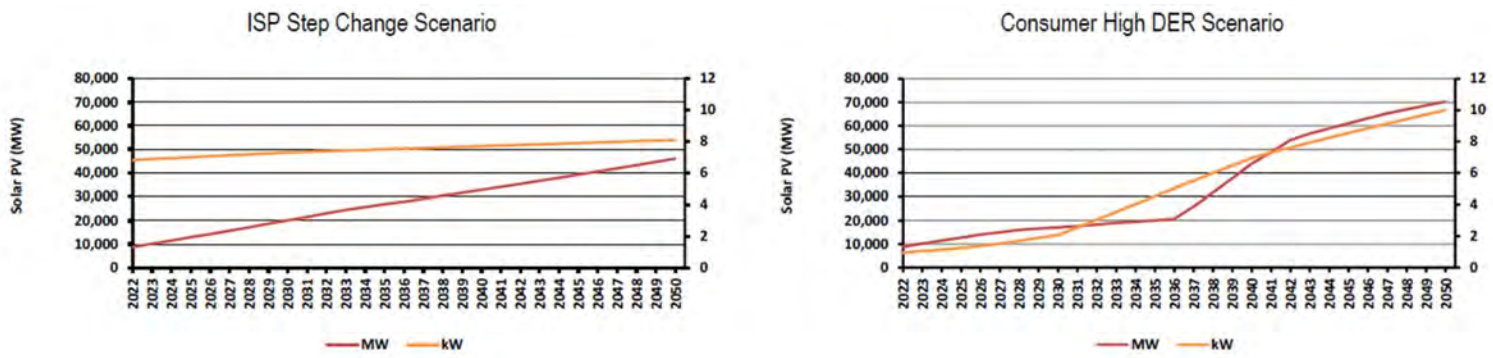
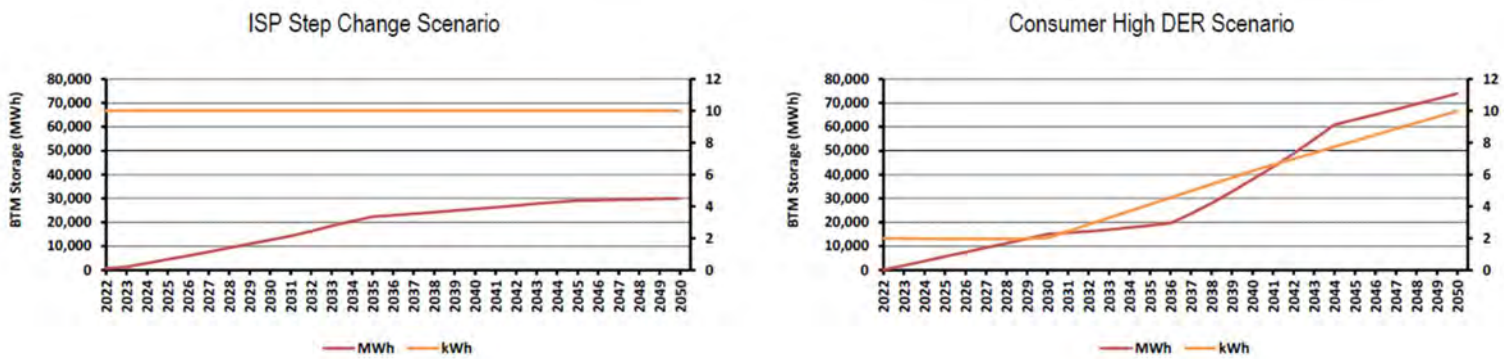
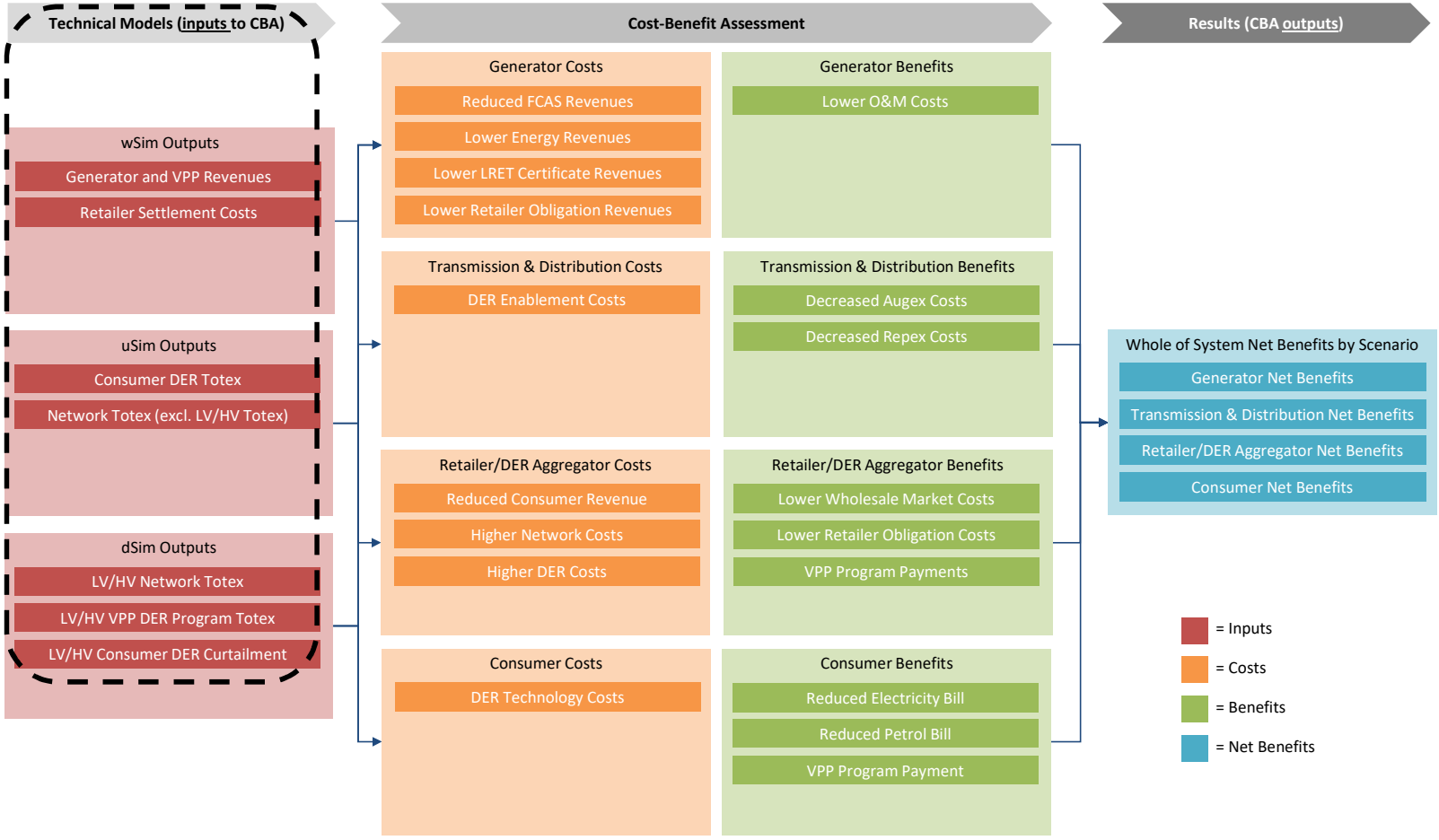


Figure 25 Comparison of residential battery storage forecasts for both scenarios in MWh



8.7 Technical modelling

Figure 26 CBA framework and relationship to technical modelling

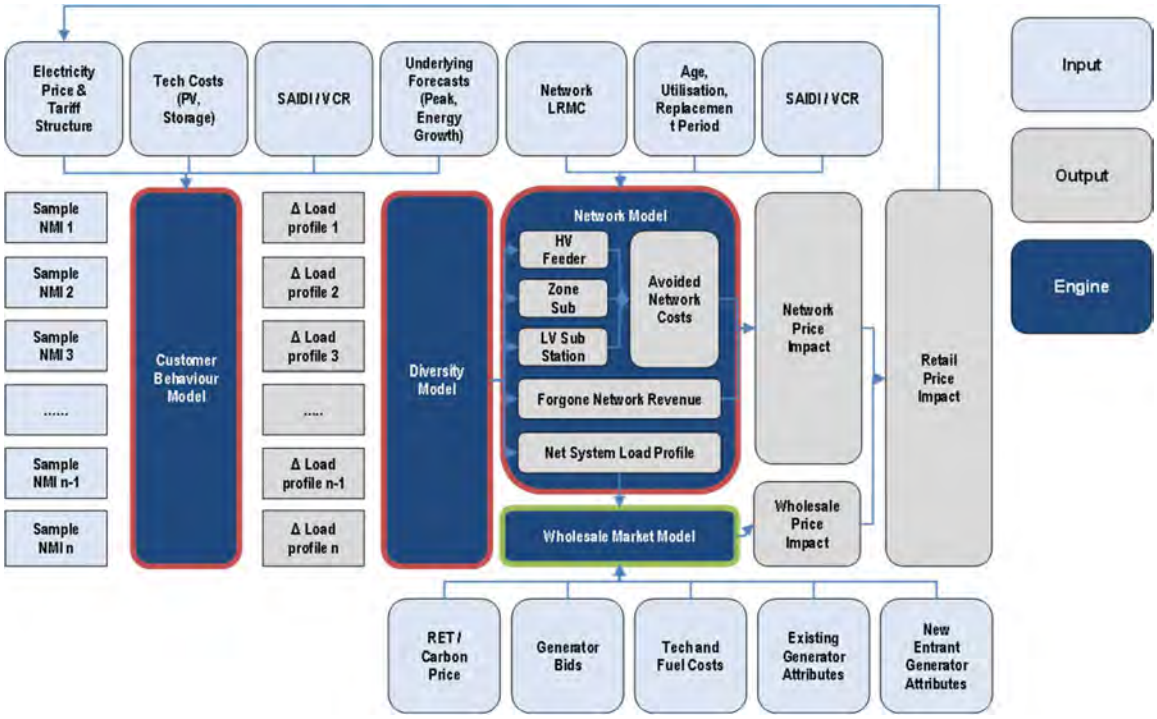


8.7.1 Whole-of-system modelling

The costs and benefits in the CBA are taken in part from the outputs of the Energeia whole-of-system modelling platform, which is comprised of modelling sub-platforms. These are summarised in the following section.

Energeia's bottom-up, whole-of-system modelling methodology is depicted in Figure 27. It shows how Energeia model customer behaviour including DER adoption, which is then turned into 30-minute interval load profiles, which are mapped to distribution and transmission assets, costs and revenues, the NEM and ultimately network and retail tariffs, which feed back into the consumer behaviour model.

Figure 27 Energeia's whole-of-system modelling methodology



Source: Energeia; Note: Red = uSim, Green = wSim

Implementation of the whole-of-system modelling methodology occurs in one of two key modelling platforms:

- Wholesale Market Simulator (wSim) – models NEM Regional Reference Prices (RRPs), resource dispatch and new entry by state, year, and scenario.
- Utility Simulator (uSim) – models customer behaviour, including DER adoption, 30-minute interval load profiles, distribution network assets, and network and retail tariffs by DNSP, year and scenario.

8.7.2 Bespoke modelling

Energeia's whole-of-system modelling is not designed to value alternative approaches to DER optimisation and visibility.

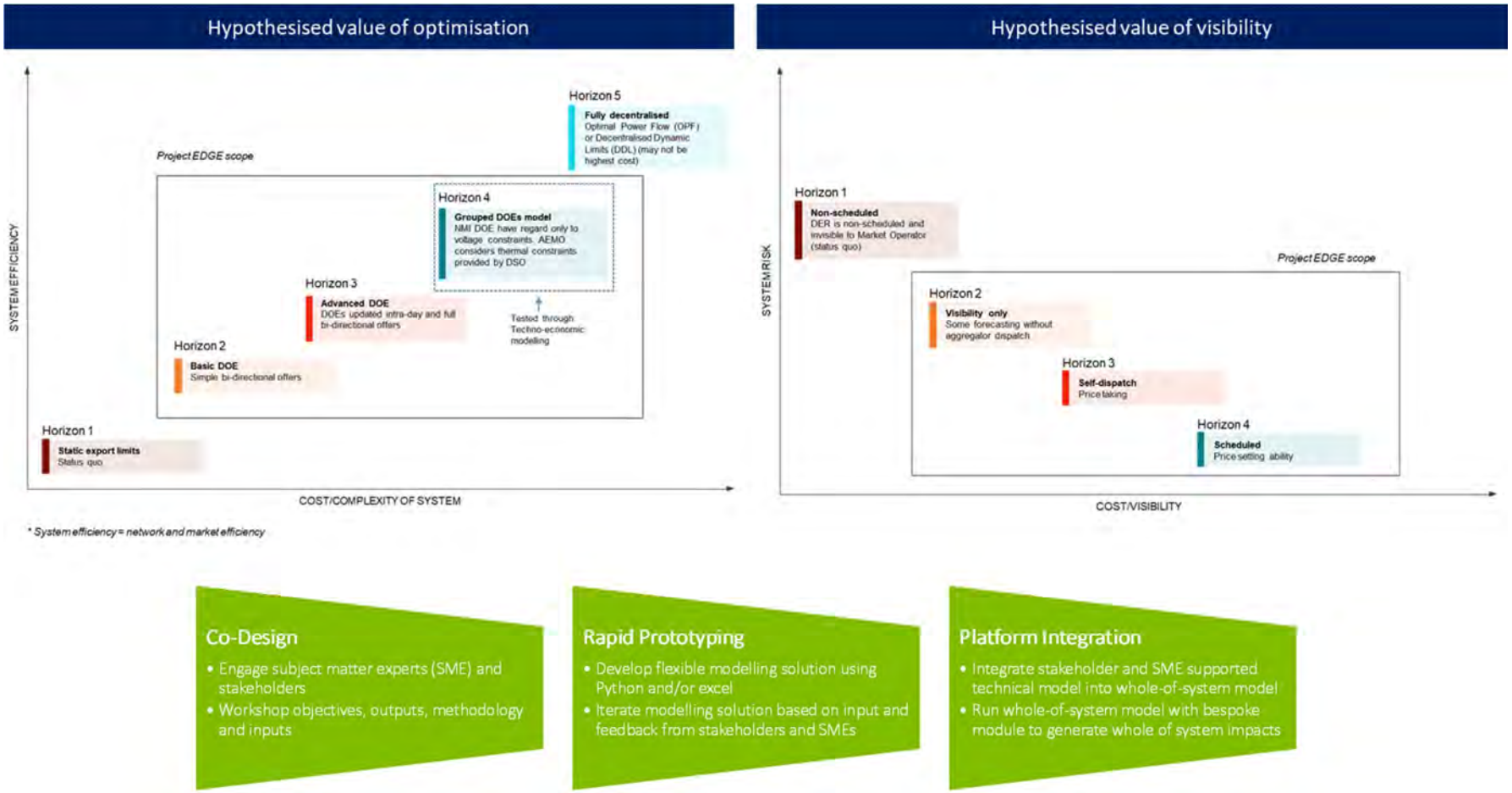
Presently, uSim models DER orchestration down to the LV network level with appropriate inputs. The modelling assumes that DER is orchestrated using perfect information and rated network capacity, and there is no modelling of imperfections in state estimation, forecasting, orchestration, or network constraints.

In order to develop appropriate real-world benefit reduction coefficients to add to the whole-of-system modelling, Energeia will develop a bespoke tool that will inform understanding of how visibility, scheduling and other key factors contribute to the optimal orchestration of DER. A key benefit of bespoke modelling is that it allows for maximum flexibility in design and implementation.

The tool will develop the estimates of the impacts of the various scenarios in terms that can be implemented in uSim.

Figure 28 illustrates the approach (in green) to developing bespoke modelling tools for estimating the value of optimisation and visibility across the range of options being considered by the project, which are summarised in the left and right matrixes below. Once the impacts of different optimisation and visibility approaches have been estimated using the bespoke tool, Energeia will add the associated functionality to the whole-of-system modelling to obtain the most accurate overall estimates possible within schedule and budget constraints.

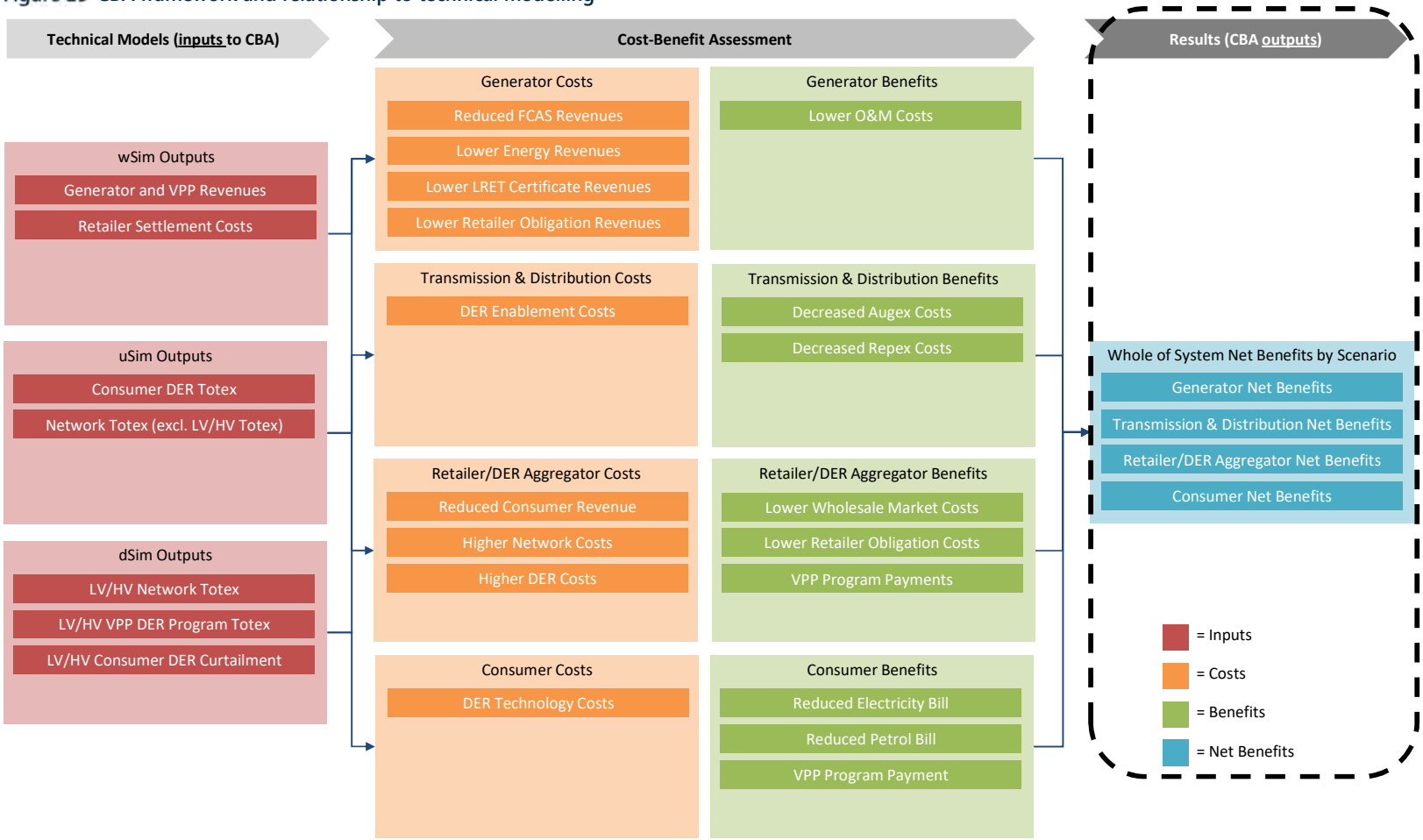
Figure 28 Approach to developing bespoke modelling tools for estimating the value of optimisation and visibility



Source: Energeia

8.8 CBA findings development

Figure 29 CBA framework and relationship to technical modelling



8.9 Costs and benefits results

The results of the CBA will be presented to directly align with relevant priorities, research questions and associated hypotheses within the UoM Project EDGE Research Plan[73].

This will form the basis for how the CBA will be interpreted as well as how summary conclusions and next steps will be developed. Table 21 shows the breakdown by which the CBA results will be presented.

Table 21 Cost benefit results breakdown

Result breakdown	Rationale
Overall net economic benefits (BCR – Benefit Cost Ratio)	The overall Project BCR summarises on a holistic level the net market benefits across the entire electricity system.
Relative to each research question	As defined in Section 8.5, the CBA assessment will focus on how outputs align to relevant priorities, research questions and associated hypotheses.
Category	Costs and benefits attributed to each category provide insight into which aspects of the market and system bear both costs and benefits. This is particularly important to assess the impact on stakeholders and consider any resulting benefits and costs transfers across the system.
Scenario	Results broken down by scenario demonstrate which DER market model maximises the value of the DER Marketplace at differing rates of DER uptake.
Bespoke modelling scenarios	The bespoke modelling of the incorporation of optimisation and visibility into the DER Marketplace will be representative relative to their impact on CBA results. This will demonstrate any incremental benefits or changes to the value proposition of the DER Marketplace. In particular, the impact of 5-minute settlement and value-stacking associated with contingency FCAS market opportunities will be explored using the bespoke approach. Some care is required to ensure that the scenarios explored in bespoke modelling – a subset of those explored in broader modelling exercises – are chosen as to be a relevant population sample of challenges and value generation potential as explored within the broader project scope.

8.10 Opportunities and next steps

Throughout CBA development, opportunities and next steps will be identified, developed and reviewed with key stakeholders.

The iterative nature of the CBA development process (highlighted by the key next steps listed below) will provide multiple touch points for stakeholders to be involved and informed:

- Finalisation of detailed CBA methodology with stakeholder input.
- CBA 'drops' at Milestone 3 and Milestone 4.
- Ongoing validation of assumptions against field trials and techno-economic modelling.
- Regular sharing of interim results/project updates with stakeholders.

[73] At https://aemo.com.au/-/media/files/initiatives/der/2022/master-research-plan-edge.pdf?la=en

Outcomes from stakeholder engagement will be primarily centred on the development of conclusions and recommendations for next steps. These will be developed and presented in the Final CBA report (mid-2023). This will include:

- Assessment of the project in alignment with its intended purpose and objectives.
- Identification of scenarios upon which project value is enhanced or transferred across the value chain.
- Impacts on consumers and scenarios which have the greatest positive or negative impact on the long-term interests of electricity consumers.
- Identification of likely rule changes and recommended positioning to progress rule changes
- Reconciliation against concurrent projects and initiatives.
- Alignment to technical requirements and broader trial outcomes.

A1. UoM Calculation Architecture

The figures below illustrate UoM's nRT and in advance DOE architecture.

Figure 30 Timing diagram for the near-real-time architecture

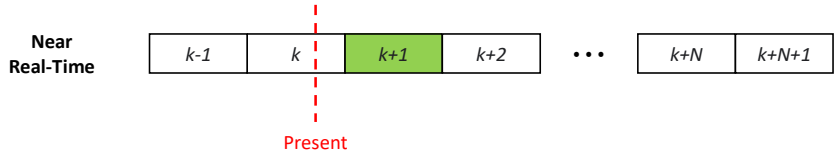


Figure 31 Near real-time architecture

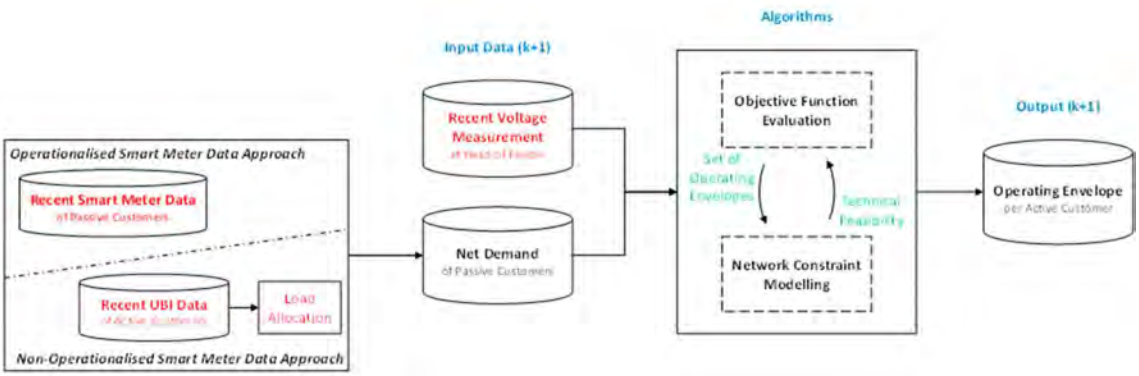


Figure 32 Timing diagram for the in-advance architecture

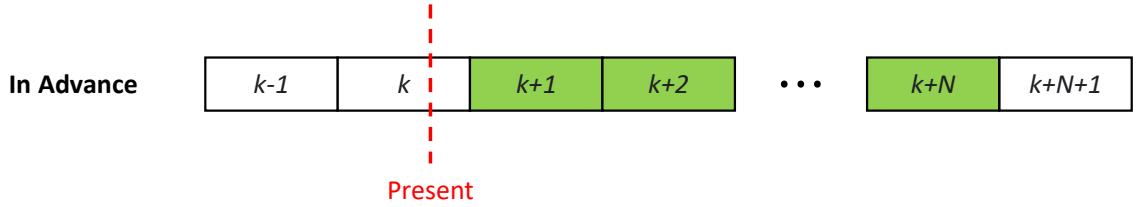
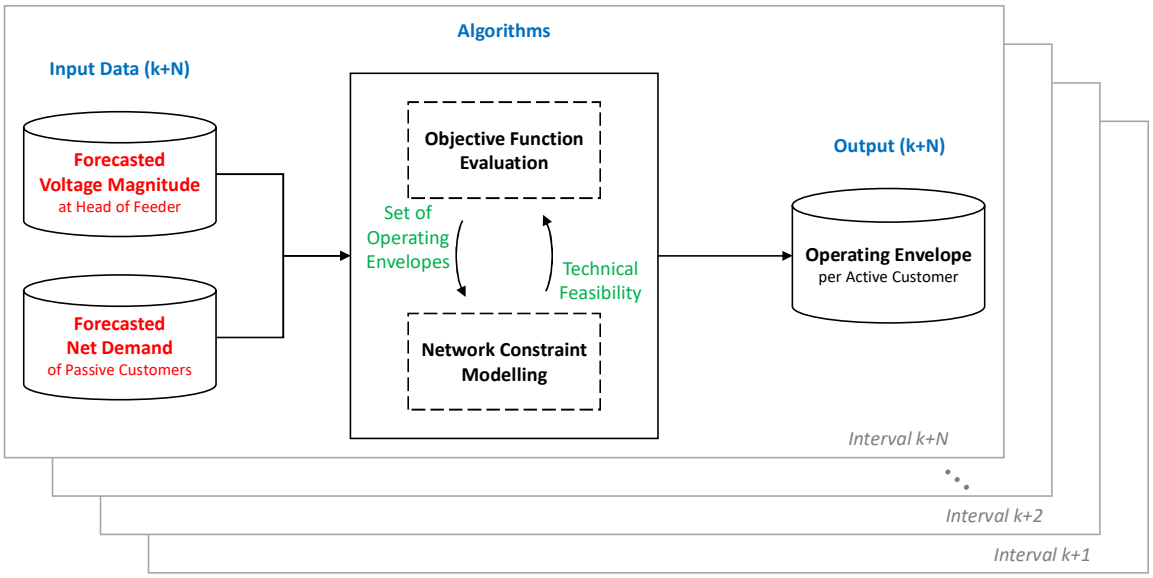


Figure 33 In-advance architecture



A2. UoM Objective Functions

The section below summarises the objective functions of allocation options designed by UoM that will be used within the field trials to test and identify the most optimal trade-off between complexity and market efficiency.

A2.1 UoM Objective Functions

Objective Function 1: Maximise aggregated services

This objective function aims to maximise the total volume of exports/imports from active customers. Fairness considerations are not incorporated. As a result, customers at the end of the feeder may end up with reduced DOE (to avoid voltage problems) while those at the head of the feeder will be able to receive larger DOEs.

Objective Function 2: Equal allocation

This objective function aims to ensure a fair allocation of network capacity among multiple active customers. That is, each customer is allocated with the same DOE. This can be done either in absolute kW/kvar or proportional to installed DER capacity. While fairness is guaranteed, depending on how sensitive customers at the end of the feeder are to voltage issues, the individual DOE can be very small. This results in a lower aggregated DOE when compared with Objective Function 1.

Objective Function 3: Weighted allocation

This is an extension based on Objective Function 1 where individual weighting factors are applied to each active customer. The weighting factors can be adapted depending on the specific scenario to reflect the priorities of stakeholders. For instance, they can be used to reflect the price of exports from each active customer in order to ensure the least cost.

A3. LSE Lifecycle

The figures below show the key phases and associated process and roles for local services under the LSE function and the LSE lifecycle master process.

Figure 34 Proposed process and roles for Local Services

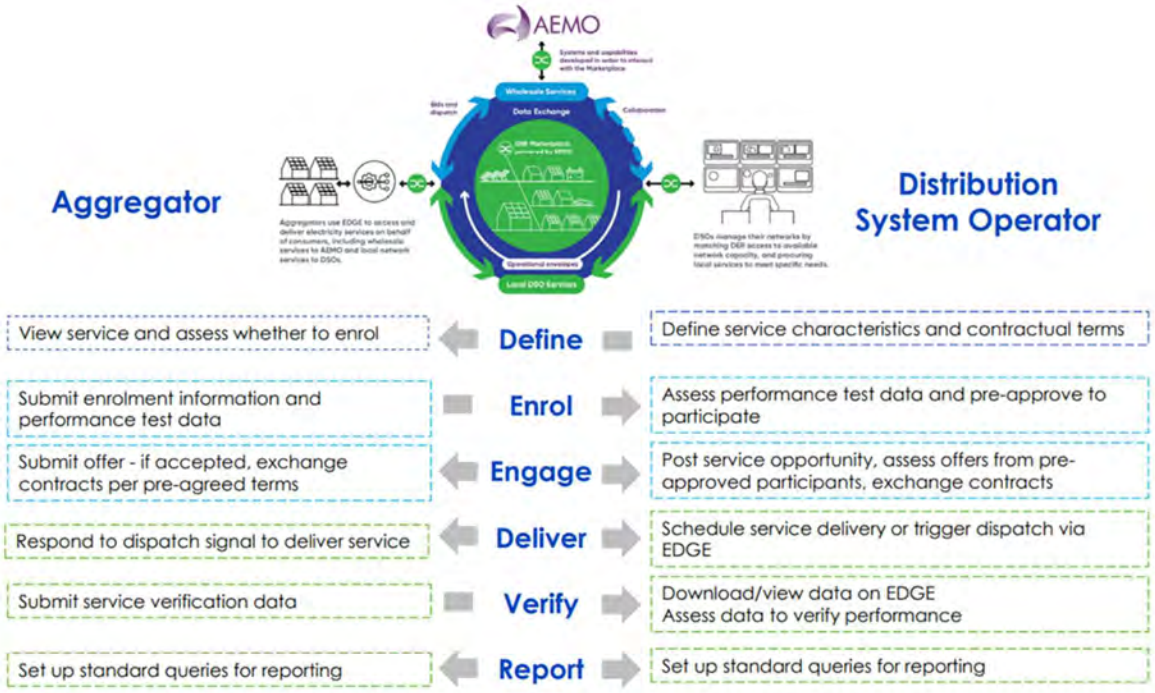
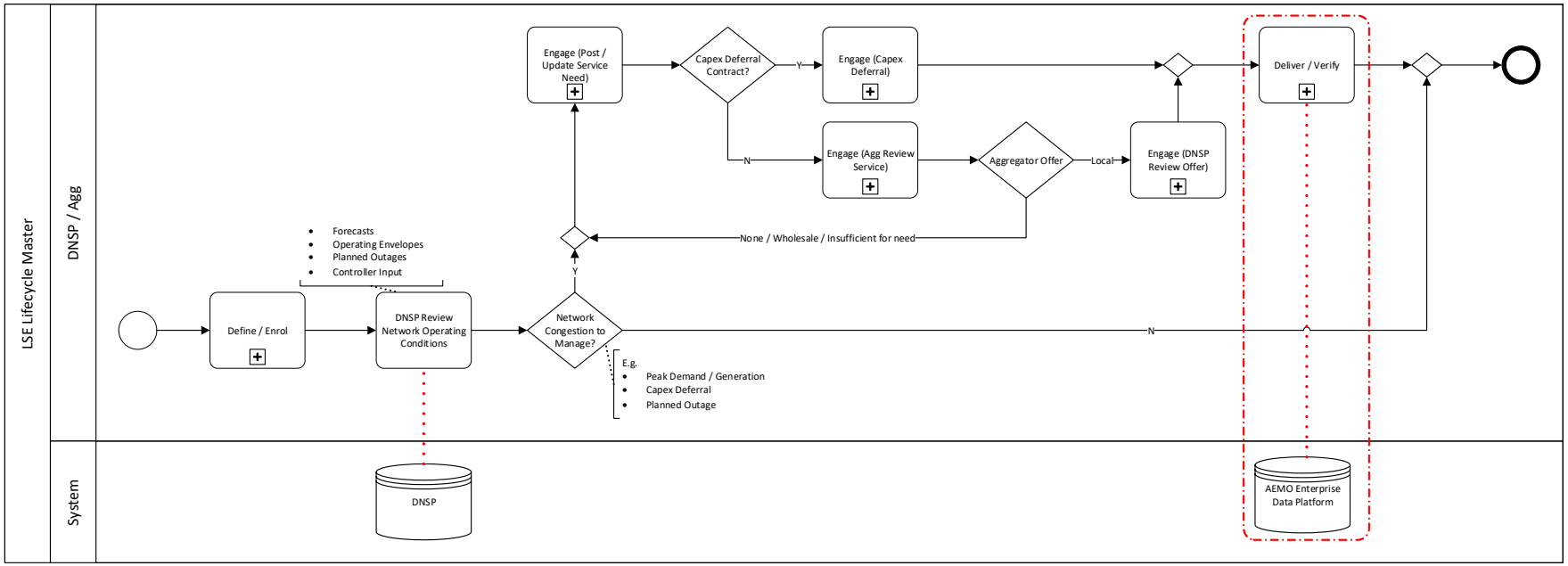
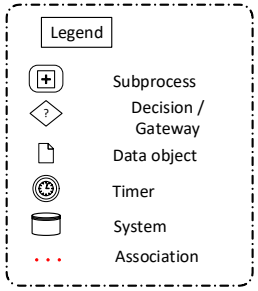


Figure 35 LSE lifecycle master process – demand high firmness





A4. LSE Standard Services

The figures below show the six LSE standard services defined in the market for Project EDGE, including proposed characteristics.

Figure 36 Standard service classifications (demand management)

Summary classification of local services

Demand increase / reduction

High Firmness
*(typically linked to a **network planning** capex deferral use-case, EDPR Augex funded)*

- **Trial example:** Feeder with high overloading probability/incidence – peak demand reduction service required
- **Future example:** Reverse power during solar PV generation peak causes sustained or regular network operation/asset issues – local generation reduction or load increase service required
- **Treatment:** Likely to require services over a prolonged period (>1year), hence suited to a longer-term contract with *guaranteed availability and agreed pricing*

Medium Firmness
*(typically linked to an **operational planning** use-case, weather related, EDPR Opex funded)*

- **Trial example:** Forecast asset overload as a result of heat wave activity or picking up additional customer load due to a planned temporary network reconfiguration - peak demand reduction service required
- **Future example:** Minimum demand system issue forecast - local generation reduction or load increase service required
- **Treatment:** Likely to require services on a seasonal basis, hence suited to a shorter-term contract with *negotiated availability and pricing*

Low Firmness
*(typically linked to a **spontaneous operational** use-case trigger, event related, EDPR Opex funded)*

- **Trial example:** Unexpected occurrence of abnormal local network loading as a result of a community event, or a combination of weather and special calendar days - peak demand reduction service required
- **Future example:** AEMO declared system contingent scenario – services required would relate to the event
- **Treatment:** Akin to NEM spot market - *no guaranteed availability, pricing is set by the market or negotiated earlier*, hence suited to a shorter-term contract with negotiated pricing

Figure 37 Standard service classifications (voltage management)

Summary classification of local services

Voltage management

High Firmness
*(typically linked to a **network planning** capex deferral use-case, EDPR Augex funded)*

- **Trial example:** LV network with known regular or sustained Code voltage breaches – local voltage management service required
- **Future example:** Support of additional DER hosting capacity (e.g. for export / EV charging) where known voltage constraints exist – local voltage management service required
- **Treatment:** Likely to require services over a prolonged period (>1year), hence suited to a longer-term contract with *guaranteed availability, agreed pricing and autonomous operation*

Medium Firmness
*(typically linked to a **forecast market need** use-case, high price related, funding to be clarified)*

- **Example:** LV network with known limited capacity for energy export/import – local voltage management service required to temporarily relieve network constraint for market economic benefit
- **Treatment:** Likely to require services on a seasonal basis or until constraints are remediated, hence suited to a shorter-term contract with *negotiated availability and pricing*

Low Firmness
*(typically linked to a **spontaneous market need** use-case trigger, event related, funding to be clarified)*

- **Example:** Opportunistic expanded local DER export / import portfolio requires additional local network capacity (market motivated, voltage limited local network) – local voltage management service required to temporarily enable increased DER activity for for market economic benefit
- **Treatment:** Likely to require ad-hoc services, hence suited to a shorter-term contract with *uncertain availability, pricing is set by the market or negotiated earlier*

→ Market service related

Figure 38 Comparison of demand management and voltage management local services classifications

Demand increase or reduction					Voltage management		
Service Characteristic	**Characteristic Description**	**Demand Increase or Reduction High Firmness (Capex Deferral)**	**Demand Increase or Reduction Medium Firmness (Operational Planning, e.g., weather related)**	**Demand Increase or Reduction Low Firmness (Spontaneous Operational, e.g., Event Driven)**	**Voltage Management High Firmness (Capex Deferral)**	**Voltage Management Medium Firmness (Forecast Market Need)**	**Voltage Management Low Firmness (Spontaneous Market Need)**
Service Type	The type of service a DNSP engages an aggregator to deliver (e.g., demand reduction or voltage management)	Demand Increase or Reduction	Demand Increase or Reduction	Demand Increase or Reduction	Voltage Management	Voltage Management	Voltage management
Firmness	Firmness indicates the certainty around service delivery, e.g., a high firmness service is very certain and has a confirmed, contractual payment structure	High	Med	Low	High	Medium	Low
Contract duration	Length of contract between DNSP and aggregator	12 - 24 months	3 months (seasonal)	3 months (seasonal)	12-24 months	3 months (seasonal)	3 months (seasonal)
Number of activations	How many times a DNSP can engage an aggregator to deliver a service over a given contractual period Min - aggregator gets paid for these activations regardless Max - aggregator cannot be called more often than this	Min and Max	Min and Max	No min or max (all activations are negotiated)	Unlimited	Unlimited	No min or max (all activations are negotiated)

Demand increase or reduction					Voltage management		
Maximum service duration	Used to assess performance at time-of-service enrolment, therefore sets the upper bounds for duration of activation	>= 4 hours	4 hours	Best endeavours (2+ hours)	Refer to droop curve	Refer to droop curve	Refer to droop curve
Pricing/Payment (Availability)	Customer is paid to be available during a particular timeframe to allow for some movement in the activation timeframe	$/kW (contractually fixed)	$/kW (negotiated per posted need) - higher rate as lower firmness	N/A	$/kVAr (contractually fixed)	$/kVAr (negotiated per posted need)	N/A
Pricing/Payment (Performance)	If customer is activated/dispatched, payment is made based on performance (verified delivery of real power)	$/kWh (contractually fixed)	$/kWh (negotiated per posted need) - higher rate as lower firmness	$/kWh (negotiated per posted need)	N/A	N/A	$/kVArh (negotiated per posted need)
Pricing/Payment (Service)	If customer delivers service through local detection, payment is made based on verified service delivery	N/A	N/A	N/A	$/kVArh (contractually fixed)	$/kVArh (negotiated per posted need)	N/A
Pre-dispatch signal	Time of signal provision by DNSP to allow the aggregator to prepare for dispatch (expressed as a number of days or hours before 'T' - i.e. start of service delivery) Note - signal will include service duration and quantity	T - 2 days	T - 1 days	T - 4 hours	N/A - Local detection	N/A - Local detection	T - 4 hours
Availability starts	Marks start of availability period	Date/time	Date/time	N/A	Date/time	Date/time	N/A

Demand increase or reduction					Voltage management		
Availability end	Marks end of availability period	Date/time	Date/time	N/A	Date/time	Date/time	N/A
Notice period	Notice that DNSP must provide to aggregator prior to commencement of service delivery (i.e. 'activation' starts)	30 minutes	30 minutes	30 minutes	N/A - Local detection	N/A - Local detection	30 minutes
Activation starts	Marks start of activation period	Date/time	Date/time	Date/time	N/A - Local detection	N/A - Local detection	Date/time
	Dispatch signal triggers start of real power service delivery	Trigger – dispatch signal	Trigger – dispatch signal	Trigger – dispatch signal	N/A - Local detection	N/A - Local detection	Trigger – dispatch signal
Activation end	Marks end of activation period	Date/time	Date/time	Date/time	Refer to droop curve	Refer to droop curve	Date/time
Location	Location of service delivery	Zone Substation/Feeder/ LV DTX/Phase/ Circuit	Zone Substation/Feeder/L V DTX/Phase/Circuit	Zone Substation/Feeder/L V DTX/Phase/Circuit	LV DTX/Phase/Circuit	LV DTX/Phase/Circuit	LV DTX/Phase/ Circuit
Real (P) amount (kW)	The amount of real power requested from an aggregator	Fixed Real kW Target (P)	Fixed Real kW Target (P)	Fixed Real kW Target (P)	Refer to droop curve	Refer to droop curve	Fixed Real kW Target (Q)
Reserve Price (WTP)	DNSP willingness to pay	N/A (availability/ performance - fixed as part of LTC)	$ (availability/ performance)	$ (performance)	$ (availability/ service - fixed as part of LTC)	$ (availability/ service)	$ (performance)