Project Edith

Knowledge Share Report

Network support: a comparison of current and emerging solutions

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We have been operating since 2007, previously trading as Enea Consulting.

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ABOUT PROJECT EDITH

Project Edith is a demonstration project currently taking place in New South Wales, Australia. It is led by electricity distributor Ausgrid and technology provider and aggregator Reposit Power, in collaboration with the Australian National University and energy software developer Zeppelin Bend.

Stage 1 of the project ran until June 2023 and demonstrated an end-to-end, dynamic approach to the decentralised management of distribution network capacity.

This report fits within an ongoing knowledge sharing engagement led by Ausgrid and Reposit Power, as part of their collaboration on Project Edith. The findings of Project Edith are intended to inform the evolution of the energy system in Australia.

THIS REPORT WAS PREPARED ON BEHALF OF

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And the Project Edith partners.

Executive summary

The Australian electricity system is changing, as people make the switch to electric vehicles and install rooftop solar and home batteries. As more of these customer energy resources – or CER – connect to the grid, the energy system is becoming increasingly decentralised.

Managing the increased two-way energy flows to and from the grid sees distribution network service providers (DNSPs) needing to develop new, more dynamic capabilities to support greater value for and from CER and facilitate the market integration thereof. In doing so, DNSPs are moving towards functioning more as distribution system operators (DSOs), using more sophisticated solutions to dynamically manage network capacity.

About this report

A study was undertaken as part of Project Edith (see below) that aimed to assess current and future approaches to evolving network support needs. In this context, network support refers to customers (typically through a customer agent, such as a retailer or aggregator) deliberately increasing or decreasing their consumption, storage or generation of real or reactive power, when signalled or requested, to support the local network.

The study focused on dynamic network pricing and procurement of network support services. It looked at how the different ways to signal network support can lead to more efficient management of distribution networks and improved customer outcomes, within the context of increasing market participation of customers' energy resources. It included an in-depth review of eight real-world case studies.

This report outlines the results of the study and fits within an ongoing knowledge sharing engagement led by Ausgrid and Reposit Power as part of their collaboration on Project Edith.

Project Edith and the evolution of the distribution network

Project Edith is a demonstration project led by Ausgrid and Reposit Power, in collaboration with the Australian National University (ANU) and network software provider Zeppelin Bend. The project is one of several initiatives[1] underway that explore the possibilities for CER to further participate in energy and services markets. At the distribution level, Australia's Energy Security Board (ESB) proposed reforms that focus on leveraging customer side flexibility and sharing value with customers. This included network support services, whereby customers or customer agents (such as retailers or aggregators) are incentivised to help manage distribution network capacity constraints, such as voltage and thermal constraints. As a result, the need for network upgrades can be deferred or avoided.

Project Edith uses time and location-specific pricing, referred to in this report as dynamic network pricing, to both signal the availability of unused network capacity to CER and manage local constraints.

1 Other similar initiatives (in Australia) are summarised in the following report: Distributed Energy Integration Program (DEIP), "DER Market Integration Trials Summary Report", September 2022. [Online]. Available: https://arena.gov.au/knowledge-bank/deip-der-market-integration-trials-summary-report/

Project Edith is testing the extent to which dynamic pricing can be used to:

- Remove barriers to the participation of customers' energy resources in energy markets,
- Allocate distribution network capacity in a decentralised manner, and
- Incentivise network support, such as voltage support.

Key findings

The report is structured around two evolving approaches to network support: procuring network support services and incentivising network support through dynamic pricing. How flexible CER can be leveraged for network support is then explored within the context of these two approaches. A particular focus is placed on Project Edith as a network support approach and how the project differentiates itself from the other case studies presented in this report.

PROCURING NETWORK SUPPORT SERVICES

Network support procurement refers to DSOs entering into agreements, directly or indirectly, with customers who own CER. In the presence of a customer agent representing customers, such as small businesses or homeowners with CER, this arrangement is typically supported by two contracts: one between the DSO and the customer agent, and one between the agent and the customer. The contract between the DSO and the customer agent is quite often more complex, whereas the latter tends to condense this complexity into a simple product offering that adequately provides customers with transparency, can be easily understood and shares value. These contracts allow the distribution system operator to manage network capacity by leveraging customer flexibility in line with the contract conditions.

Centralised flexibility marketplaces are emerging as an evolution of the bilateral agreements that have traditionally been used to procure network support. These marketplaces can be region-specific, whereby each DSO has its own marketplace, such as Piclo Flex in the United Kingdom, or can allow multiple DSOs to leverage shared infrastructure for related data exchange, such as the Local Service Exchange trialled by Project EDGE in Australia. While marketplace platforms and capabilities are still maturing, the use of a flexibility marketplace is intended to encourage competition within the market for network support.

INCENTIVISING NETWORK SUPPORT THROUGH DYNAMIC PRICING

In Australia, the initial rollout of cost-reflective network pricing has focused on time-varying pricing, where the variation is typically static (such as Time-of-Use), and prices are applied consistently over a large and diverse network area (postage-stamp pricing). This means that while prices change over different times of the day, these variations are the same for every day (or type of day, such as weekday or weekend, or winter or summer). Time-varying price structures can better represent the long-run costs of using the network, compared to flat-rate tariffs. However, time-varying structures are usually not targeted enough to incentivise the responses needed to relieve a specific constraint and defer network augmentation.

Dynamic network pricing leverages existing concepts of time-varying network pricing and introduces additional layers of sophistication. This approach takes advantage of new, price-responsive CER and technology enabled automation to ensure pricing is still simple for customers to understand while being more efficient. Because using time and location-specific incentives can target actual network conditions at a granular level, DSOs can encourage a better use of available network capacity and incentivise behaviours that support the local network. This is not the case when using network-wide, static price signals.

Accounting for features such as daily weather, CER penetration, local network characteristics, and typical demand and generation within the local area, dynamic pricing is emerging as an alternative way to signal when and where network support is needed and remove price barriers where it is not. Instead of directly procuring network support services, pricing signals incentivise customers to respond in a way that supports improved network management. Dynamic pricing components for both imports (load) and exports (generation) could be published for each defined sub-section of a distribution network. As such, the frequent signalling of where there is value available (including through negative tariffs that 'pay' for the provision of services) enables customer agents, on behalf of customers, to optimise across their portfolio and maximise their value stack.

It is important to highlight that dynamic, five-minute or real-time pricing already exists and is being deployed to customers, just not necessarily by DSOs. In Australia, one example would be the wholesale energy price. Australia's national electricity market, the NEM, operates on five-minute increments for wholesale settlement. As such, customer agents are already managing the associated opportunities and risks that dynamic pricing presents, and packaging these pricing structures into a wide variety of customer offers. Project Edith takes this existing concept of near-real-time pricing and leverages this to signal location-specific conditions in the network.

LEVERAGING FLEXIBLE CER FOR NETWORK SUPPORT

This study found there is considerable variety in how flexible CER are used for network support. With this variety in mind and given the relatively low level of maturity of current network support solutions – with most yet to be commercially rolled out – we found that it may be more relevant to assess the different options for the design and implementation features of each solution as opposed to the solutions more broadly. These options are referred to in this report as 'variations' and the features of each solution as 'dimensions'. Ten dimensions were identified that characterise the different network support solutions – from how support is signalled to the firmness, or certainty, of the customer's response.

Of the ten dimensions, four were deemed most fundamental to understanding the impact of the different solutions, from the DSO, customer agent and customer perspectives – they relate to the business model of the solution itself, while the other six dimensions relate to the solution's delivery model. **These four business model dimensions** play a crucial role in the DSO's ability to address network constraints, the customer agent's business model and value proposition to the customer, and the customer's economic reward.

Four business model dimensions

The four dimensions fundamental to understanding the impact of different solutions are:

1. **Activation mechanism,** which describes how the DSO signals or incentivises the provision of network support. This dimension is most fundamental to characterising network support,
2. **Payment type and recurrence,** the process to compute or settle upon the price paid and the frequency of that payment,
3. **Firmness,** the certainty around the service delivery, and
4. **Pricing types,** the elements for which payment is received. This can be on a per unit or aggregated basis, and impact how the service delivery is valued.

Four measures

The impact of each dimension's associated variations on performance against **four measures** was qualitatively assessed as part of this study.

The four measures represent the value unlocked – for the DSO, customer agent, and customer – and the ease of implementation. Value is represented by measures one and two, while ease of implementation is represented by measures three and four:

1. **Customers' ability to manage preferences.** The ability for customers to meet their own needs while simultaneously providing network support,
2. **Adjustability.** The ability to adjust parameters of the solution and/or response to target specific constraints, and deliver a lean and 'fit for purpose' response by CER,
3. **Simplicity.** The ability to deliver network support while limiting the need to go through additional processes, platforms, overheads and challenges.
4. **Scale-up feasibility.** The extent to which the processes and technologies underpinning the solutions are readily available (in the case of CER, to participate in network support), and capable to scale-up (on the DSO, customer agent and customer sides).

It is assumed that a set of capabilities to manage the variability introduced by CER will be developed by most, if not all, DSOs in Australia in the next three to five years. These capabilities are for example related to the implementation of dynamic operating envelopes (DOEs), the computation of which will require granular modelling and forecasting capabilities to identify constraints. The development of these capabilities will benefit all solutions discussed in this report, which rely on granular inputs to succeed at scale. In the comparison of solutions, it was assumed that for more dynamic solutions, this capability build-up lowers the additional cost while enhancing the benefits that could be unlocked (for all participants).

Key characteristics of Project Edith as a network support approach

Project Edith differentiates itself from the other case studies presented in this report, in that it combines a series of interesting characteristics that:

- Offer flexibility in when and how customer resources participate in network support and energy markets. This means that the expected firmness of customers' responses can be lower than in procurement approaches but the customers' ability to manage their preferences is often higher.
- Keep options for the DSO open – as the approach does not lock in long-term infrastructure investment. This value is heightened in the current investment context, with high levels of uncertainty around the future technology and market settings that might impact customers' evolving use of the network.
- Circumvent traditional challenges faced by procurement approaches, such as baselining and verification. These processes can be lengthy for both the DSO and the customer agent (especially baselining[2]).
- Leverage capabilities and systems that already exist, such as network pricing and existing connection agreements, or are currently being built, such as dynamic operating envelopes capabilities. This makes the approach simpler to implement within the Australian context.

Prepare for multiple future scenarios, in that the solution can be adjusted to meet the needs of DSOs, customer agents, and customers in most network scenarios. This is done without introducing additional mechanisms that could end up acting as barriers, inhibiting future evolutions of the energy system.

2 Baselining refers to the process to quantify the energy that would have been generated, stored, or used by the customer if the network support service was not being delivered. Put simply, the baseline represents what the customer would 'normally' do.

Figure 1

Summary of key characteristics of Project Edith, compared with other network support approaches

Measure	Outcome	Direct procurement	Centralised marketplace	Project Edith
Customers' ability to manage preferences	Enables customer choices	✗	✓	✓
Adjustability	Preserves optionality for the future (no long-term investment lock in)	? Depends on system used	? Whole new system	✓ Integrated system
	Maximises firmness of response	✓	✓ Depends on the service	✗
Simplicity	Avoids traditional demand response challenges such as baselining or specific contracting	~ Most do not	~ Most do not	✓
Scale-up feasibility	Builds on currently established capabilities, such as network pricing and billing	✗	✗	✓
	Leverages future expected capability developments, such as LV forecasting or DOE signalling	? Possibly	✓	✓

Network support: three areas for future investigation

Based on this study's comparison of current and emerging solutions, three main areas for future investigation were identified. These are outlined below.

These areas relate to how best to use and manage dynamic, flexible approaches to CER and network support. Exploring these areas in more depth could support greater use of CER for network support in Australia and facilitate the scale-up of the solutions presented in this report.

INVESTIGATE WHETHER THE CHOICE FOR SIMPLE SOLUTIONS IS STRUCTURAL OR SITUATIONAL

Further work is needed to demonstrate whether – in a world where smart CER are abundant, capabilities are built on the DSO and the customer/agent side, and the required processes are in place – a cost-benefit assessment will favour sophisticated solutions over 'simple' solutions.

EXPLORE TO WHAT EXTENT MULTIPLE APPROACHES TO NETWORK SUPPORT COULD RUN IN PARALLEL

There is still a need to understand whether a single, 'one-size-fits-all' solution is possible, or if future needs will have to be met by multiple complementary solutions that run in parallel. One possible future could see dynamic pricing managing most of the network's needs, through targeted incentives for controllable, discretionary energy resources such as home batteries. This could be complemented by targeted use of direct bilateral arrangements or a simplified marketplace arrangement where firm responses are required (most likely procured from large customers).

QUANTIFY THE VALUE THAT NEW APPROACHES TO MANAGING NETWORK CONSTRAINTS UNLOCK AND ASSESS HOW THIS IS SHARED WITH CUSTOMERS

New approaches to managing network constraints refers to approaches that can be adapted to reflect the actual network conditions. The quantification of costs and benefits that DSOs, customer agents and customers will be exposed to has been identified as an important next step for scaling up new approaches to managing network constraints. In the case of the major Australian projects, work to assess the costs and benefits of each project is already underway.

Contents

Glossary

Aggregator | An aggregator is a company that operates a virtual power plant, coordinating customers' energy resources to provide services to the electricity system.

Baseline | The energy used or produced by customer energy resources at a given point in time, without providing a network support service.

Bilateral contract | An agreement between the distribution system operator and a counterparty to provide a defined network support service or set of services. Counterparties commonly include customer agents or large commercial and industrial customers themselves.

Central marketplace | A single market platform through which services are procured, such as network support services or wholesale services to address system needs. A flexibility marketplace for network support can have varying levels of centralisation, from each DSO operating its own marketplace for a given distribution network or region to a single entity operating the marketplace for all networks or regions.

CER | Customer energy resources. Distributed energy resources that are owned by a retail customer and connected to the distribution network such as generation, storage, flexible load and/or management hardware and software. Common examples include rooftop solar, home batteries, electric vehicles and controllable hot water systems.

Connection point | The agreed point of electricity supply established between a customer and distribution network. Currently also the settlement point for energy markets.

Constraint | The point at which the level of energy traversing through a network reaches the technical limits (e.g., thermal or voltage) that the network can support.

Customer agent | A third party that represents a customer in a market and, for example, manages a customer's CER to gain financial benefits from participation in energy markets on behalf of the customer. This role is typically fulfilled by an aggregator or retailer.

DNSP | Distribution network service provider. DNSPs operate and maintain the distribution network, including infrastructure such as power poles, wires, transformers, and substations. They are responsible for the transportation of electricity. Sometimes referred to as distribution network operator (DNO).

DSO | Distribution system operator. A DSO is an uplift in the capabilities of the DNSP to provide a dynamic network service that supports more value for and from CER.

Dynamic network pricing | Network tariffs that change in response to real-time conditions. Dynamic prices can reflect the long-run marginal cost of providing electricity in those conditions or the market equilibrium price for the available network capacity.

Flexibility | The ability and willingness of a customer to change (often through technology enabled automation) the way that real or reactive power is consumed, generated or stored by their electrical equipment.

Network services procurement | Contractual arrangements between distribution network service providers and customers with CER, typically via customer agents, for the provision of network support to help manage the distribution network.

Network support services | Customers (typically through a customer agent, such as a retailer or aggregator) deliberately increasing or decreasing their consumption, storage or generation of real or reactive power, when signalled or requested, to support the local network. Network support services are typically used to defer or avoid the need for network upgrades.

Peak load or peak demand | Terms used interchangeably to denote the maximum power requirement of a system at a given time, or the amount of power required to supply customers at times when need is greatest. They can refer either to the load at a given moment or averaged over a given period.

Voltage management | Deliberately fluctuating voltage to maximise available network capacity and/or to ensure voltage remains within allowed limits on the grid under varying operating conditions. This can be achieved by different means, from traditional voltage regulators to active management of active or reactive power injection or absorption in a local network area.

Two-sided market | Two-sided markets commonly refer to a construct where buyers and sellers meet to exchange a product or service – in this report, energy. In the context of the Energy Security Board (ESB)'s reforms, a two-sided market could support an efficient balance of electricity supply and demand whilst enabling all consumers to realise the value of their CER and demand flexibility.

VPP | Virtual power plant. VPPs are a network of distributed resources that are coordinated to deliver power system and energy market services.

1

Introduction

To provide context for the report findings, this introduction covers some relevant aspects of the Australian energy market as well as the immediate challenges facing the energy system and distribution network. It then considers the current and emerging approaches to using flexible customer energy resources, or CER[3], for network support. In the context of this report, network support refers to the event where customers, typically through a customer agent (most commonly a retailer or aggregator), deliberately increase or decrease their consumption, storage or generation of real or reactive power, when incentivised, to support the local network.

This section includes:

3 A subset of customer energy resources (CER). This report uses CER throughout, to emphasise that these resources are owned by customers.

1.1 CER in the current market context

In Australia, residential customers are at the forefront of the decarbonisation and decentralisation of energy systems, as they are installing more rooftop solar and home batteries and buying electric vehicles.

The role of CER in the energy system is evolving, as these resources become more sophisticated over time. While the majority of CER installed in Australia today is passive – in that it is not actively managed or controlled by the customer or their agent – new possibilities are emerging for CER with 'price responsive' capabilities to participate in energy markets, including the ability to receive and respond to external signals such as prices.

This presents new opportunities for customers, customer agents, and distribution network operators – known in Australia as distribution network service providers, or DNSPs – and the energy system more broadly. Opportunities enabled by smarter CER include:

- Lower emissions from the electricity grid, by contributing to a higher penetration of renewable energy sources,

- Energy bill optimisation for customers who own these CER, by maximising self-consumption and accessing wholesale and network value streams, and
- More efficient distribution network. Smarter, coordinated CER can support the deferral or avoidance of network augmentation. Network utilisation is improved and can be optimised as well.

While CER presents an immense range of opportunities for the end-to-end energy system, there are barriers to the efficient market integration of these resources that require further consideration. This includes a need for the approach to distribution network management to evolve.

1.2

The evolution of the distribution network

At the distribution level, the power system has historically been designed to deliver electricity from centralised generators to customers. CER enable customers to generate electricity on-site and export any spare energy back to the electricity system. This process creates two-way energy flows. Managing and rectifying the thermal capacity issues and voltage variations emerging on the low voltage (LV) part of the network – as part of adapting a one-way grid to manage more two-way energy flows – is a growing challenge.

To meet this challenge, DNSPs are developing a range of more dynamic capabilities. As DNSPs enable more dynamic capabilities and services, they shift away from only operating a network that provides electricity to customers. This new paradigm sees DNSPs innovate services and enable customers to participate in energy markets and provide local network support (typically through customer agents). This transition is commonly referred to as DNSPs becoming distribution system operators (DSOs).

In Australia, a major focus has been on managing the impacts of exports from rooftop solar systems on the electricity grid. To do this, DSOs have used operating envelopes, which are limits placed on customers' imports and exports of energy. These limits tend to be static over time and location. This means they do not reflect the actual network constraints at a given point in time and for a given location [1].

In this context, dynamic operating envelopes, or DOEs, are emerging as a more efficient way to manage distribution network capacity. Dynamic operating envelopes change the upper limits on customers' load and generation. These flexible limits can vary over time and location, depending on the available capacity in each area of the network. As such, DOEs provide a way for DSOs to signal to, or request, customers to deliberately increase or decrease their consumption, storage, or generation of real or reactive power.

While DOEs can be used to manage local network capacities and constraints, this report considers DOEs to be complementary to network support. The eventual implementation of DOEs is associated with a significant capability build-up that will see DSOs improve the granularity and accuracy with which they model the low voltage network and identify network constraints. DOEs will also see more coordinated and optimised responses from CER, on the customer side.

1.3

Leveraging flexible CER for network support

The industry is collaborating on a range of reforms to remove the barriers to efficient CER integration and unlock the full potential of these resources. Notably, Australia's Energy Security Board (ESB) has proposed a suite of reforms to facilitate arrangements to reward customers with flexible demand or generation for responding to market conditions. These reforms address the following broad challenges:

1. **Technical** integration of CER – to ensure that CER operates within the system's limits and that the grid can accommodate the continued uptake of CER.

2. **Market** integration of CER – to unlock value for and from CER, by enabling customers to engage with the energy market and ensure they are adequately rewarded for their flexible demand and generation [2].

At the distribution network level, the ESB's proposed reforms have focused on enabling DSOs to manage the network in a cost-effective way. It is envisioned that this will include network support services, whereby CER provide capacity to the local network. As a result, the need for costly network upgrades can be deferred or avoided.

There are several solutions that DSOs can use to signal when and where network support is needed. These vary in their level of maturity as DSO, customer agent and CER capabilities continue to evolve. Some examples include time-varying network pricing, procurement of network support services (through bilateral contracts or a central marketplace) and dynamic network pricing. The evolution of these approaches is described further in **Section 2**.

Beyond reducing or delaying network expenditure, network support services also provide considerable value to DSOs by keeping options open – as they do not lock in long-term infrastructure investment. This value is heightened in the current investment context, with high levels of uncertainty around the future technology and market settings that might impact customers' evolving use of the network. Not only do network support services help to manage network constraints, they also bring new opportunities for residential customers and their agents by increasing available value streams.

Customers without CER also benefit. By reducing or deferring the need for network investment, network support can lower the overall costs for DSOs to serve customers. This is passed on to customers, including those who are not CER owners, through lower network prices.

1.4

About this report

This report fits within an ongoing knowledge sharing engagement led by Ausgrid and Reposit Power, as part of their collaboration on Project Edith.

It assesses the different ways that DSOs can signal and value the use of flexible CER for network support within the context of increasing market participation of customer energy resources. This assessment is informed by an in-depth analysis of the current landscape of ideas, which was conducted as part of this study. By reviewing other projects that share similar objectives to Project Edith, both in Australia and the United Kingdom (UK), this study sought to better understand how Project Edith fits into the bigger picture. Extensive desktop research, including reviewing the latest industry reports and available project materials, was conducted. This was complemented by targeted discussions with the project owners of multiple demonstration projects and network support programs.

To understand how the different solutions result in more efficient management of distribution networks and to articulate where Project Edith sets itself apart, **three key questions** were considered:

- What is the current state of maturity in the market for network support?
- What are the different approaches at play and how do these compare?
- What still needs to be done to maximise the opportunities these approaches create?

While this report focuses on Project Edith and the opportunities that the dynamic network pricing solution it is demonstrating presents, it also contributes to a larger body of work on the market integration of CER.

The report seeks to highlight the different characteristics of various approaches to using flexible CER for network support. It summarises each solution's relative ability to unlock benefits for DSOs, customer agents and customers. While the DSO occupies a central place in this report (given that the need for network support is fundamentally a need of the DSO), the implications for customer agents and customers are also discussed.

To do this, the study considered the dimensions that characterise the different network support solutions – from how support is signalled to the firmness, or certainty, of the customer's response. The contribution of each dimension to a range of desired outcomes is also qualitatively assessed. These outcomes are represented by four measures: customers' ability to manage preferences, adjustability, simplicity, and scale-up feasibility.

2

Network support: current landscape of ideas

Integrating CER in a way that is efficient for distribution networks and the broader energy system, while enabling customers to access more value, requires an uplift in DSOs' capabilities. A focus of this DSO capability uplift has been exploring new ways to engage with the customer side through various capabilities and solutions. Without these in place, the increase in CER penetration will likely result in a need for significant investment in new network infrastructure.

The way DSOs are engaging with customers to address distribution constraints and manage the use of the network is evolving. However, engaging with the customer side – known as demand management – is not new. Traditionally, demand management solutions have included direct load control, behavioural demand response and tariffs. Up until now, many of these solutions have tended to be used in response to system level or wholesale aspects. At the distribution level, the focus has been on managing maximum demand – typically a widespread and persistent constraint.

With the rise of CER and the impacts these resources are having on how and when customers use electricity, new uses for solutions at the distribution level are emerging. DSOs are now needing to adapt, as they respond to emerging challenges such as minimum demand and rapidly changing constraints that are also often highly localised.

This section focuses on the evolving approaches to network support:

2.1 Procuring network support services

2.2 Incentivising network support through dynamic pricing

2.1 Procuring network support services

One approach to managing distribution network constraints is procurement of network support services. These services are procured through dedicated mechanisms, separately from network pricing. As such, this approach typically requires a separate reconciliation process (outside of the existing billing processes and systems). In the context of this report, procurement refers to DSOs entering arrangements with customers who own CER. Where a customer agent is present, this arrangement is typically underpinned by two contracts

– one between the DSO and the customer agent, and one between the agent and the customer. The contract between the DSO and the customer agent is often more complex while the latter tends to compact this complexity into a simple product offering that can be easily understood by customers.

These contracts offer customers and their agents an opportunity to provide flexibility to the distribution network, by managing their CER accordingly, when required by the DSO. Requirements often stipulate an increase or decrease in the consumption or generation of real or reactive power. To manage a network constraint at a granular level, dispatch is set for specific times and locations, based on agreed advance notice period and conditions. Depending on the terms of agreement between the DSO and the customer agent, the DSO compensates the agent for participation and/or service delivery. The customer agent then shares some or all of this value with the customer (CER owner), depending on the customer agent's business model and product offering. Compensation is typically linked to a baselining process, whereby an estimation is made of what the customer's energy consumption or provision would have been if the CER had not participated in network support. The payment subsequently received is then computed based on the difference between the baseline and the actual consumption/provision of real or reactive power. The different pricing structures and payment types are discussed further in **Section 4.2**.

DSOs typically decide whether to pursue network support services based on a cost-benefit assessment. This considers the costs and benefits of network support against the counterfactual – investing in network infrastructure. The regulatory investment test (RIT-D) framework defines the consultation requirements (for Australia) based on the scale of investment identified by the DSO. The market consultation and procurement processes are typically lengthy and costly to both the DSO and the responding counterparties, such as customer agents.

Centralised flexibility marketplaces are emerging as an evolution of the bilateral agreements that have traditionally been used to procure network support. These marketplaces can be region-specific, whereby each DSO has its own marketplace, such as Piclo Flex in the United Kingdom, or can allow multiple DSOs to leverage shared infrastructure for related data exchange, such as the Local Service Exchange trialled by Project EDGE in Australia. While marketplace platforms and capabilities are still maturing, the use of a flexibility marketplace is intended to encourage competition within the market for network support.

Using demand response initiatives to incentivise targeted responses

DSOs can use voluntary demand response initiatives – in that customers choose whether to opt-in and participate – to engage customers in a targeted manner. This can support improved network management.

Typically, customers who sign up to a demand response program will receive a message asking them to change their energy usage – to either increase or decrease their consumption of electricity from the grid. These messages are sent to specific locations where an occasional constraint emerges, such as during extreme weather events, and a response is required. Those who respond receive a reward for doing so. For example, a cash payment or a discount on their next electricity bill.

Baselining for network support services

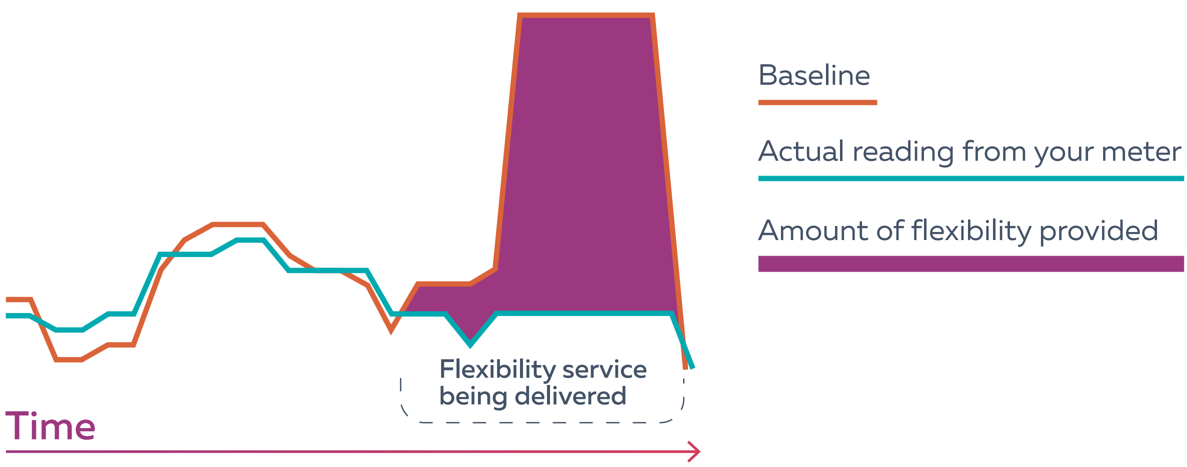
WHAT IS A BASELINE?

The baseline represented below refers to the energy that would have been generated, stored, or used if the network support service was not being delivered. Put simply, it is what the customer would 'normally' do. Baselines are used to quantify the change that occurs once network support is dispatched – the amount of support that is delivered. The amount of network support delivered is the difference between the meter reading and the baseline, as illustrated in **Figure 2**.

Multiple baselining methods exist, with some emerging approaches currently being tested. The approach used can depend on the type of CER, availability of data and quality thereof, and the technical capabilities of the DSO or customer agent (depending on where the obligation to create the baseline falls).

Figure 2

Using the baseline to compute the amount of network support delivered [3]



CHALLENGES ASSOCIATED WITH BASELINING

In most cases, baselining has been recognised as a significant challenge due to the lack of historical data, computational intensity of updating the baseline frequently, and lack of applicability to multiple use cases. Payments for network support are tied to baselining and as such, an inadequate baselining approach increases the risk of rewarding customers who did not participate and vice versa.

Furthermore, relying on baselining to measure the amount of network support can have equity implications between customers. A baselining approach tends to focus rewards on customers whose load or generation patterns are susceptible to causing constraints, at the expense of customers with load patterns that are not.

HOW PROJECT EDITH AVOIDS BASELINING

Incentives within Project Edith are not based on changes in behaviour from any perceived normal level, but rather based on actual network use. As a result, no comparison with a baseline is needed. Customers are rewarded, or charged, depending on their network use and the specified network price, just as they are today, with the only difference being that the price is dependent on actual network conditions.

2.2

Incentivising network support through dynamic pricing

INTRODUCING TIME-VARYING NETWORK PRICING TO DRIVE A SHIFT IN NETWORK USAGE

Network tariff reform encourages DSOs to implement pricing that is more cost-reflective – in other words, that sends more efficient price signals to customers [5]. In Australia, the initial rollout of cost-reflective network pricing has focused on time-varying pricing, where the variation is typically static. This means that while prices change over different times of the day, these variations are the same for every day (or type of day, such as weekday or weekend, or winter or summer). Time-varying pricing has been enabled by the emergence of interval meters[4] and increasingly, smart meters[5].

Requirements in the National Electricity Rules, or the NER, encourage network pricing that reflects the different peak and off-peak times (Time-of-Use tariff [6]). Beyond this, many tariff trials are underway across the national electricity market, the NEM, to incentivise customers to shift demand to negative and low-price periods during excess solar generation (two-way load and generation tariff [7]).

Pricing structures that are not cost-reflective, such as flat rate tariffs, have been recognised as a barrier to optimal investment in CER. By using more cost-reflective pricing, DSOs can drive a shift in network usage across time, to manage distribution network conditions. However, time-varying network pricing does not adequately address highly localised constraints that only appear on specific areas of the distribution network.

4 Interval meters are electronic meters that record how much electricity is used every 30 minutes. This allows for different electricity rates for usage at different times of the day, for example a Time-of-Use tariff [16].

USING DYNAMIC NETWORK PRICING TO REFLECT ACTUAL NETWORK CONDITIONS

Dynamic network pricing leverages existing concepts of time-varying network pricing and introduces additional layers of sophistication. This approach takes advantage of new, price-responsive CER and advanced automation to ensure pricing is still simple for customers while also efficient. By using time and location-specific incentives that better reflect actual network conditions, rather than network-wide incentives, DSOs can encourage the use of available network capacity and reward behaviours that support the local network. Factors that can be considered when calculating dynamic prices include:

- typical demand and generation within the local area,
- daily weather,
- CER penetration in each area, and
- local network characteristics.

With these features in mind, dynamic pricing is emerging as an alternative way to signal when and where network support is needed. Instead of directly procuring network support services, pricing signals incentivise customers to respond in a way that supports improved network management. Dynamic pricing components for both imports (load) and exports (generation) are published for each defined sub-section of a distribution network. As such, the frequent signalling of where there is value available (including through negative tariffs that 'pay' for the provision of services) enables customer agents to optimise across their portfolio and maximise their value stack. For instance, DSOs can dynamically signal to customers when there is an abundance of solar energy in a neighbourhood. Customers may then choose to take advantage of these lower prices and charge their EVs or batteries in response to the price signals.

5 Smart meters digitally record energy use and send this information back to a customer's energy retailer remotely, for example every 30 minutes. As such, these meters also allow for Time-of-Use pricing. Smart meters also have a range of other capabilities, like allowing the electricity supply to be remotely switched on or off and measuring the power quality at a premises [19].

From a network perspective, dynamic pricing could allow customers to respond in a way that prevents a forecast constraint from emerging at all. However, customers may also choose to respond in a way that indicates where investment is needed to address the constraint [8]. For example, continued use of the network even when prices are high would indicate to the DSO that network investment is required in that specific area.

It is important to highlight that dynamic five-minute or real-time pricing already exists and is being deployed to customers, just not necessarily by DSOs. In Australia, one example would be the wholesale energy price. Australia's national electricity market, the NEM, operates on five-minute increments for wholesale settlement. As such, customer agents are already managing the associated opportunities and risks that dynamic pricing presents. They are also already packaging these pricing structures into a wide variety of customer offers. Project Edith takes the existing concept of near-real-time pricing and evolves this to also be location-specific.

Unlocking value with dynamic pricing in Project Edith

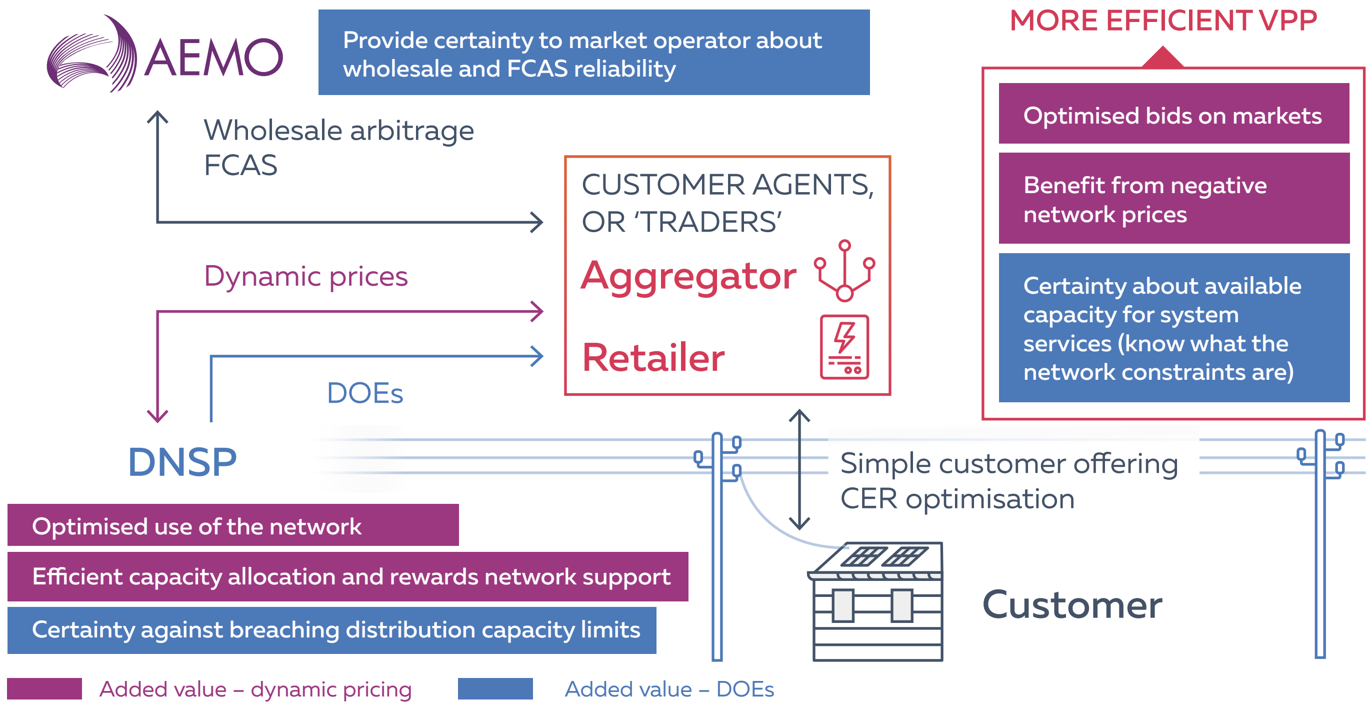
Project Edith's primary objective is to support participation of price-responsive CER in two-sided markets by using dynamic network pricing to remove artificial pricing barriers. Further details on how Project Edith unlocks more value for and from customer energy resources can be found in the Project Edith – Project Overview Report [8]. The main value streams that the decentralised approach unlocks are shown in **Figure 3**.

Dynamic pricing lets the customer agent optimise its bids on the markets and benefit from negative network prices, whilst ensuring transparency on available capacity and certainty to market operators about wholesale and FCAS[6] reliability. In this way, additional value can be unlocked for and from CER within the bounds of existing energy markets and systems.

6 Frequency control ancillary services (FCAS) are used to manage the security and stability of the electricity system. System frequency is managed through FCAS.

Figure 3

Maximising value through a dynamic pricing approach



3

Deep dive: how does dynamic pricing work in Project Edith?

A key feature of dynamic pricing is that it builds on existing capabilities, as a sophistication of network pricing. As such, it bypasses some of the cumbersome processes that other solutions, which are in addition to network pricing, currently face. This includes contracting, bidding, baselining and reconciliation.

A successful, scaled up implementation of the approach put forward in Project Edith will, however, require sufficient historical data on customer responses and improved modelling of price-elasticity curves. These inputs and capabilities are still in development. Once those capabilities are deployed, the benefits unlocked are expected to increase and at a diminishing cost; with maturity, dynamic pricing is expected to become a cost-efficient, scalable and generalisable way to signal network support.

This section explores the merits of, and capability uplift required for, dynamic network pricing:

3.1 Leveraging existing capabilities

3.2 Avoiding costly contracting and baselining processes

3.3 Promoting customer choice

3.4 Building new capabilities for a successful rollout of dynamic pricing

3.1 Leveraging existing capabilities

While Time-of-Use and demand tariffs take a step towards cost-reflective network pricing by attempting to represent the cost of using the network at times of congestion, these pricing structures do not incentivise a targeted response. Because the prices are based on averages, both across time and location, the impact they can have on network constraints is dampened.

Project Edith builds on cost-reflective pricing structures and existing network pricing capabilities to deliver more targeted outcomes. The dynamic prices being demonstrated are dependent upon both time and location and can therefore impact actual system constraints. Project Edith uses dynamic pricing to incentivise customers to use their CER flexibly, thereby supporting smarter management of the available network capacity.

The proposed approach also leverages emerging capabilities that are being developed in parallel, towards the implementation of dynamic operating envelopes. Dynamic pricing benefits from the systems and processes currently being developed to implement DOEs, by using similar data inputs to DOEs such as weather, CER information and LV network modelling to identify network constraints at a granular level[7]. Project Edith also proposes publishing dynamic pricing through the platform used for publishing DOEs. This leverages the integrations with customer agents, through application programming interfaces (APIs), that will be needed to implement DOEs.

3.2

Avoiding costly contracting and baselining processes

The procurement of network support services requires a constraint to first be identified and then studied, as outlined in **Section 2.1**. This is commonly followed by a request for proposal, negotiations between the DSO and customer agent, and contracting. Once services are contracted, there is ongoing dispatch and delivery management. Typically, a baseline also needs to be established before service delivery can be verified. These processes are costly and time consuming, for both the DSO and the customer agent (depending on where the obligation to create the baseline falls). They can also be highly dependent on the market environment.

Where a central marketplace is used, additional overheads associated with implementing and running a platform for bidding, and perhaps dispatch, are introduced.

Dynamic pricing, on the other hand, requires few additional capabilities beyond what is already done today. Dynamic pricing can be accommodated within existing customer connection agreements and does not face the same measurement and verification challenges, such as baselining. While some of the legacy approaches to service procurement (such as direct control) may have equally low overheads as dynamic pricing, this is often achieved by taking a widespread, less-targeted approach. Such solutions may not prove optimal, from both a DSO and customer/agent perspective, in a high CER future where price-responsive capabilities exist at scale.

3.3

Promoting customer choice

If dynamic prices do become a standard network offering, it is envisioned that this would be on an opt-in basis for customers who choose to engage with the energy market. For those customers who do opt for dynamic prices, how they manage the complexity associated with the dynamic pricing incentive structures is up to them.

It is expected that most customers will engage with the market through a relevant customer agent, such as a retailer or aggregator. In this set up, the customer agent is responsible for managing the complexity of pricing on their behalf and packages these prices up into a simple customer offering. However, some customers may choose to do it all themselves. This would require a retailer that passes through dynamic pricing, while the customer manages their own resources and responses.

7 Where relevant, procurement and central marketplace approaches may also leverage these emerging capabilities.

For example, by making use of advanced automation and control features provided by some energy management system suppliers, or other technology service providers.

Project Edith does not prescribe a specific customer offering – how the agent passes dynamic pricing through to customers is up to them, depending on their individual business model and offerings. This promotes customer choice, by leaving the customer to choose the offering they find most attractive, based on their needs and preferences.

3.4

Building new capabilities for a successful rollout of dynamic pricing

Managing constraints using dynamic network pricing relies on new processes for setting network tariffs. Previously, pricing has worked in a single direction whereby the customer paid the DSO (through their retailer). Using pricing as a signal for CER to help the network, such as during peak times, requires location-specific two-way pricing[8]. Location-specific pricing already features in some distribution networks, by offering customers different static tariffs for different regions. However, these are currently limited, with two to three larger ‘zones’ considered. More granular and dynamic pricing will require further investments in DSO systems to be fully realised.

To this end, a better understanding of customer demand elasticity curves is needed to inform price setting. Demand elasticity refers to how much customers are willing to change their behaviour in response to a given price or reward. More still needs to be understood about the behaviour and responsiveness to changes in prices of the customers. Especially where network support is concerned, it will be important that DSOs are able to compute just how much they need to ‘pay’ for the provision of services to ensure sufficient response. Project Edith seeks to inform the development of a market equilibrium price that takes into consideration customers’ responses to changing prices. As dynamic prices mature, they can be used to find the short-run equilibrium of demand and supply to calculate market equilibrium prices.

8 On the customer side, smart meters will most likely be needed to receive these prices. Note that in most cases, new CER installations are coupled with smart meters already. The continued rollout of smart meters is expected to improve the quality and quantity of the available data inputs for computing dynamic network prices.

4

Characterising the approaches to network support

Eight case studies were reviewed as part of this study, with each case study providing an example of a different approach to using flexible CER for network support. We evaluated the various options for the design and implementation features of each approach to network support rather than the solutions more broadly. These options are referred to as 'variations' and the features of each solution as 'dimensions'.

In this review, we identified ten dimensions that characterise the different network support solutions. Of these ten dimensions, four were deemed most fundamental to understanding the impact of the different solutions. These **four business model dimensions** play a crucial role in the DSO's ability to address network constraints, the customer agent's business model and value proposition to the customer, and the customer's economic reward. One such dimension is the activation mechanism, which describes how the DSO signals or incentivises the provision of network support. The options, or variations, that exist for this dimension are (1) Direct consumption and generation control, (2) Centralised optimisation, and (3) Pure incentives.

A qualitative assessment of the dimensions was conducted using four measures, to better understand the impact of the design and implementation choices a DSO can make. The measures are intended to capture the DSO, customer agent and customer outcomes. This assessment provides insight into the relative performance of each variation of a given dimension.

It is assumed that a set of future capabilities will be developed by most, if not all, DSOs in Australia in the next three to five years [9]. These capabilities are factored into the assessment presented and relate to the implementation of dynamic operating envelopes, the computation of which will require granular modelling and forecasting capabilities to identify constraints.
The development of these capabilities is to the benefit of all solutions discussed in this report, which rely on granular inputs to succeed at scale. This capability build-up will lower the additional cost of these solutions while enhancing the benefits that could be unlocked (for all participants).

This section presents the case studies considered and provides a comparison of the business model dimensions along which these vary. Specifically, it covers the:

4.1 Overview of the case studies reviewed in this study

This study included an in-depth review of eight real-world case studies. The case studies provide examples of existing and emerging approaches to using flexible CER for network support. During the long-listing and selection process, additional weight was placed on case studies that were already completed or are ongoing (but in the implementation phases), to maximise the key learnings that could be inferred. An overview of the key features of each case study, as well as a progress update, is presented in **Table 1**.

Table 1 **Summary of the case studies**

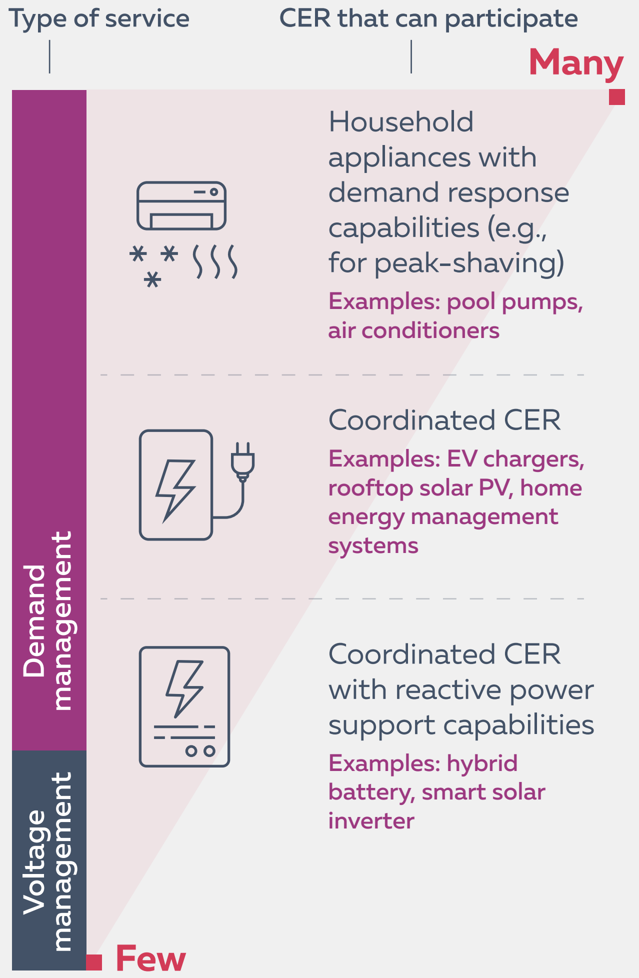
	DSO	LOCATION	SOLUTION FOR NETWORK SUPPORT	STATUS
Project Edith	Ausgrid	NSW Australia	**Dynamic network pricing**	**Demonstration ongoing** Rapid demonstration delivered with one customer agent. Trial now continuing with expansion to multiple agents
CONSORT	TasNetworks	TAS Australia	**Procurement** Bilateral contracts for fixed dispatch payments Dynamic network pricing for energy reserve/energy usage payments	**Trial completed** Results informed development of DOE concept and simpler pricing algorithms to support scalability, as demonstrated in Project Converge [10] and Project Edith
Project EDGE	AusNet	VIC Australia	**Procurement** Bilateral contracts and central marketplace	**Demonstration completed** CER Marketplace tested, with stand-up of Local Services Exchange
PeakSmart	Energex Ergon Energy Network	QLD Australia	**Procurement** Direct control	**Ongoing at scale** At-scale implementation across Energy Queensland networks
Project Symphony	Western Power	WA Australia	**Procurement** Bilateral contracts	**Pilot project ongoing** 'Go live' milestone achieved, with pilot to be completed by mid-2023
Future Flex	National Grid	Multiple regions UK	**Procurement** Bilateral contracts	**Trial completed** Preparing for scale-up of Sustain-H network support service
Piclo Flex	UK Power Networks	Multiple regions UK	**Procurement** Bilateral contracts with flexibility providers identified through central marketplace	**Ongoing at scale** At-scale implementation, with future procurement rounds lined up
Project Transition	Scottish and Southern Electricity Networks	Oxfordshire UK	**Procurement** Bilateral contracts and competitive procurement through central marketplace	**Demonstration completed** Following Trial Period 3, the projects have undertaken a Technical Trial to gain further feedback and insights

Several key themes, which relate to the implementation and scale-up of network support, consistently emerged across most of the case studies. In particular:

- The use of flexible CER for network support is at an early stage of implementation, with very few examples operating at scale. Where a solution has progressed from the testing phase and is now rolled-out at scale, its implementation and design has focused on simplicity. This simplicity has meant that these solutions do not adequately address highly localised constraints and has dampened the value that is shared with the customer and their agent.
- Distribution system operators are still developing the capabilities and processes to adequately value the use of flexible CER for network support. This includes (1) Determining the value of the local network support, and (2) Measuring and verifying the network support provided by CER. Baselining, where required, presents a considerable overhead for the DSO and the customer agent (depending on where the obligation to create the baseline falls) associated with point (2) above. However, alternative baselining techniques[9] are emerging. These techniques do not rely as heavily on determining how each specific customer would have otherwise behaved.
- Customer recruitment is an overarching barrier to scaling the use of flexible CER for network support. Recruiting customers continues to be costly and time consuming for customer agents. In Australia, this is driven by relatively low customer awareness, the nascency of the market, and the low penetration of smart CER with the capabilities required to participate in emerging products and services. This last point is illustrated in **Figure 4**.

9 One alternative approach to historic baselining is the use of diversity model profiles, whereby a 'diversity factor' is applied on demand profiles for similar customer groups and technology types. Diversified demand profiles are often already used for wider distribution network modelling and planning [20].

Figure 4 **Type of services and the corresponding CER that can participate**



4.2

Framework used to compare network support

This study, as well as a separate review of the landscape of ideas [11], found that there is considerable variety to how flexible CER are used for network support. With this variety in mind and given the relatively low level of maturity of current solutions – with most yet to be commercially rolled out – we found that it may be more relevant to assess the different options for the design and implementation features of each solution as opposed to the solutions more broadly. These options are referred to in this report as 'variations' and the features of each solution as 'dimensions'.

The analysis found that ten dimensions are most characteristic of this variety. These ten dimensions are outlined in **Table 2** and relate to both the design and implementation of the different solutions. The dimensions characterise how network support is activated or incentivised, the types of constraints addressed and the type of CER that can provide the requested support (in that the resources can respond to the signal). The dimensions also characterise the spatial and temporal granularity at which network support is signalled, the type of payment and the frequency with which these payments are made.

Of the ten dimensions summarised in **Table 2**, the first four play a crucial role in the DSO's ability to address network constraints, the customer agent's business model and value proposition to the customer, and the customer's economic reward. These dimensions are (1) Activation mechanism, (2) Payment type and recurrence, (3) Firmness, and (4) Pricing type. This section focuses on these four business model dimensions.

The remaining six dimensions relate to the delivery model of network support – the technical aspects of network support and the mechanics underlying the solutions. Further discussion on these can be found in Appendix A – Other dimensions considered as part of this study.

Table 2

Dimensions characterising the diversity of network management solutions

		DIMENSION	VARIATIONS			
BUSINESS MODEL	1	Activation mechanism	• Direct consumption and generation control	• Centralised optimisation	• Pure incentives	→ p.29
	2	Payment type	• Fixed	• Dynamic	• Negotiated	→ p.32
		Payment recurrence	• One-off	• Recurring		
	3	Firmness	• Low	• Medium	• High	→ p.34
	4	Pricing types	• Existence	• Availability and utilisation	• Utilisation	→ p.36
DELIVERY MODEL	5	Type of CER	• Household appliances with demand response capabilities	• Coordinated CER	• Coordinated CER with reactive power support capabilities	→ p.46
	6	Type of service	• Demand management	• Voltage management	• Both	→ p.48
	7	Geographic resolution of the signal	• Network	• Zone substation (ZSS) / Feeder / LV line	• Connection point	→ p.50
	8	Time scale (for setting the price)	• Upfront	• Year ahead / Seasonal / Month ahead	• Day ahead / Intra-day	→ p.52
	9	Time scale (for signalling network support)	• Upfront	• Year ahead / Seasonal / Month ahead	• Day ahead / Intra-day	→ p.52
	10	Forecasting approach	• Historical approximation	• Heuristics	• Optimal power flow	→ p.55

4.3

Comparison of the four business model dimensions

This section provides a qualitative assessment of each of the four business model dimensions, considering them from the DSO, customer agent and customer perspectives. This assessment assumes an average case scenario for each of the variations, rather than reflecting the decisions of a single project (apart from Project Edith, given the scope of this report). As such, this assessment should be viewed as a general representation of the concepts presented, to which there will be exceptions in a real-world context.

The assessment considers the impact of each dimension's associated variations on performance against four measures, whereby variations are ranked relatively from lowest to highest in their ability to achieve a desired outcome. The four measures represent the value unlocked – for the DSO, customer agent, and customer – and the ease of implementation.

Value is represented by measures one and two, while ease of implementation is represented by measures three and four:

1. **Customers' ability to manage preferences.** The ability for customers to tailor their participation in the energy system to meet their own needs and convenience. For example, where a customer seeks to maximise their self-consumption of electricity, they will only provide network support when doing so is aligned with their personal objective.

2. **Adjustability.** The ability to adjust parameters of the solution and/or the response, to target specific constraints and respond to network conditions. This supports the delivery of a lean and 'fit for purpose' response by CER.

3. **Simplicity.** The ability for the DSO to signal and CER to deliver network support without needing to go through additional processes, platforms, overheads and challenges.

4. **Scale-up feasibility.** The extent to which processes and technologies are readily available (in the case of CER, to participate in network support), capable to be implemented and operate at scale (on the DSO, customer agent and customer sides).

To best reflect the value unlocked – for the DSO, customer agent, and customer – this assessment would ideally rely on the outputs of cost-benefit analyses. In the absence of such analysis[10], measures one and two have been selected to reflect the value to:

- **The DSO.** Adjustability considers the DSO's ability to implement the least cost solution, or that which minimises unnecessary use of network support.
- **The customer agent.** Adjustability captures the customer agent's ability to maximise their value stack, participate in markets and optimise across their portfolio.
- **The customer,** captured through the customers' ability to manage preferences.

10 Based on the best available information at the time of writing this report. The need for such analysis, to quantify the costs and benefits associated with network support, is further discussed in **Section 6.3**.

Dimension 1

Activation mechanism

POSITIONING THE VARIATIONS

Most of the case studies analysed favour a more direct activation mechanism, whereby network support is still centrally dispatched albeit with varying degrees of certainty and optimisation. Project Edith is the only example amongst the case studies that considers a pure incentives approach.

Table 3 **Defining the activation mechanisms**

	DIMENSION	VARIATION 1	VARIATION 2	VARIATION 3
1	**Activation mechanism** The mechanism used by the DSO to signal or incentivise the provision of network support.	**Direct consumption and generation control** The power consumption or generation of CER is directly moderated by the DSO (for example, using ripple control[11]) during network events. Examples include direct load control and remote disconnect / reconnect.	**Centralised optimisation** The use of the distribution network is optimised for lowest cost, considering market needs and/or local network constraints. Examples include scheduled dispatch and central market platforms.	**Pure incentives** Price signals are used to incentivise the flexibility for network support. Examples include dynamic network pricing.

11 Ripple control is a common form of direct control, whereby a higher-frequency signal is superimposed on the standard main power signal. When receiver devices attached to non-essential loads (such as pool pumps, air conditioners) receive this signal, the appliance shuts down until the signal is disabled.

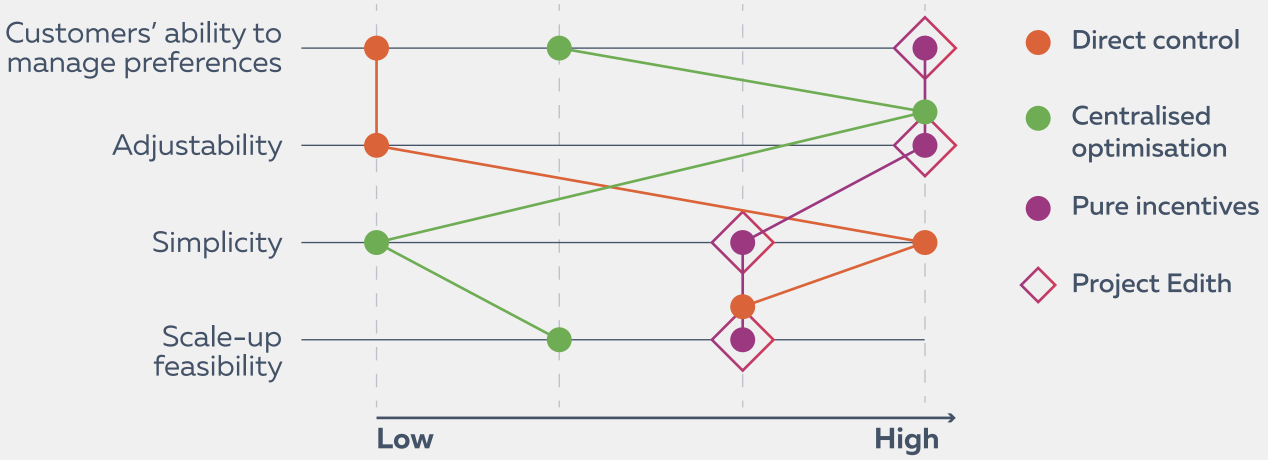
Dynamic operating envelopes or dynamic network pricing – which is used when?

In the decentralised model demonstrated in Project Edith, Ausgrid does not explicitly allocate distribution network capacity to connection points. Rather, Ausgrid provides signals (through dynamic network pricing) that are used by the customer or their agent to decide and optimise on the capacity used. This approach seeks to support more value for and from CER, by providing CER with the maximum access to use the network to participate in markets.

In situations where dynamic prices alone do not provide sufficient certainty against breaching the network's operational limits, a safeguard is needed. In Project Edith, this safeguard is provided by dynamic operating envelopes or DOEs. Project Edith is testing the use of DOEs as 'guardrails' to maintain the network within these limits.

Figure 5

Assessing the activation mechanisms against the performance measures



KEY OBSERVATIONS ABOUT THE ACTIVATION MECHANISM

The assessment presented in **Figure 5** is based on the following observations:

- While direct control is suitable for CER that are not equipped with smarter capabilities , the relevance of a control-based approach to more sophisticated resources is unlikely to be optimal. This is because there is 'lost' productivity associated with the unused smart capabilities. The 'lost' productivity refers to the value that could be unlocked by price-responsive CER but is not, because these resources are not being exposed to the correct signals.
- Centralised optimisation typically requires using an additional bidding and dispatch platform, thus increasing the complexity of the solution. In addition, centralised optimisation may still have to go through the traditional challenges linked to baselining, which once again increases complexity. Conversely, the delivery of the services would be firmer than in a pure incentives approach. Firmness is explored further in **Dimension 3 – Firmness**.
- In contrast, pure incentives enable customer agents managing a portfolio of smart, price-responsive CER to operate their fleets more efficiently and maximise their value stack through exposure to a range of market signals in parallel. Compared to direct control and centralised optimisation, a pure incentives activation mechanism also gives independence to customers around their choice to participate in network support.
- It is important to note that, when compared to direct control, centralised optimisation and pure incentives can both have the advantage of allowing customer agents to stack local and wholesale value streams (in other words, participate in multiple markets) and deliver these services simultaneously, which direct control does not.

WHAT DOES PROJECT EDITH DO?

Overall, there has been a very low number of price-responsive CER among smaller customer groups (particularly residential) until now. This is partly because of how new these technologies are, but it also results from the lack of price incentives to encourage the uptake of advanced CER, given the prevalence of flat rate tariffs. As a result, a pure incentives approach has not previously been cost-effective in the Australian context.

Project Edith leverages the rising penetration of these technologies to deliver a pure incentives approach for signalling network support that is adjustable, simple and scalable. Furthermore, pricing leverages existing capabilities and is likely to require lower overheads compared to procurement approaches, as detailed in **Section 3.1** and **Section 3.2** respectively.

Qualifying the costs of using CER for network support

When it comes to assessing the costs borne by the DSO for each of the activation mechanisms, the point in the process at which these costs emerge should also be considered. Generally, costs are either upfront, ongoing or on a per transaction basis. A qualitative analysis of the expected costs is provided in **Table 4**. This analysis assumes the average case scenario for each variation and is an average representation of the concepts presented.

Table 4 **Analysing the additional cost items borne by DSOs at different stages of the process of using CER for network support**

Applicable to both direct control and centralised optimisation mechanisms

	DIRECT CONTROL	CENTRALISED OPTIMISATION	PURE INCENTIVES
Contract customers and their agents	**Low +** Establish contract directly with the customer	**High +++** • New DSO function / capability • Drivers: How many services are contracted? What type of services?	**Low +** • No additional contracts needed between customer and DSO or between customer agent and DSO • Separate contract between the customer and their agent
Recruit customers	**High +++** • Low customer awareness • Relatively low uptake of smart CER • Small, nascent VPP market in Australia		**Medium/high ++** • See points on the left • Recruitment can be lower cost, especially if the option is opt-out • Note that the approach taken by Project Edith is an opt-in model
Setup IT solution(s) to map network support to identified constraints	**Medium ++** • Analyse the available CER portfolio(s) • Compute scale of response required (proportion of resources to dispatch) and availability		**Medium ++** Integrate the network model and telemetry with the pricing engine
Setup IT solutions to define signals (dispatch, dynamic prices)	**Low + to High +++** • Depends on whether the approach relies on existing ripple control infrastructure • Schedule may be pre-defined	**High +++** • Establish market platform for bidding • Integrate dispatch with operational platform(s)	**Medium/high ++** Develop the dynamic pricing engine
Setup mechanism to price network support	**Low + to High +++** Depends on whether an existing or separate pricing mechanism is used		**Low +** Automated through the dynamic pricing engine
Operate solution	**Medium ++** • Relies on existing operational capabilities • Where ripple control is used, relies on ongoing maintenance of aging systems	**High +++** • Ongoing delivery management • Ongoing operating expenditure (OPEX) for using the platform(s)	**Medium/high ++** • Upskill existing capabilities • Ongoing OPEX for using the platform
Measurement and verification	**Low +** • Delivery is (supposed to be) certain • Need to check that the CER responded	**High +++** Costly and computationally intensive to 1. Establish the baseline, and 2. Compare performance against the baseline	**Low +** • Use existing metering infrastructure • Incorporate data into demand elasticity modelling
Settle with and pay customers/ agents	**Low +** Depends on payment type (typically a fixed, one-off payment)	**Medium ++ to High +++** Depends on billing capabilities and platforms required	**Low + to Medium ++** Depends on upgrades to existing billing processes and systems that are required

From **+** relatively low cost to **+++** relatively high cost

Dimension 2

Payment type and recurrence

POSITIONING THE VARIATIONS

The use of recurring payments is common across the cases studied, with the amount that is paid for service delivery most often fixed. Project Edith is the only current example of a dynamic pricing approach[13], whereby the DSO is the price setter and updates this price frequently. There are limited examples of negotiated pricing, which can incur a lengthy and iterative bidding process between the DSO (or a central entity) and the customer (or their agent). In the instance where negotiations are conducted through an integrated bidding platform, the bidding process could be less complex.

12 It is important to highlight that five-minute or real-time pricing already exists and is being deployed to customers, just not necessarily by DSOs. In Australia, one example would be the wholesale energy market. This is further detailed in **Section 2.2**.

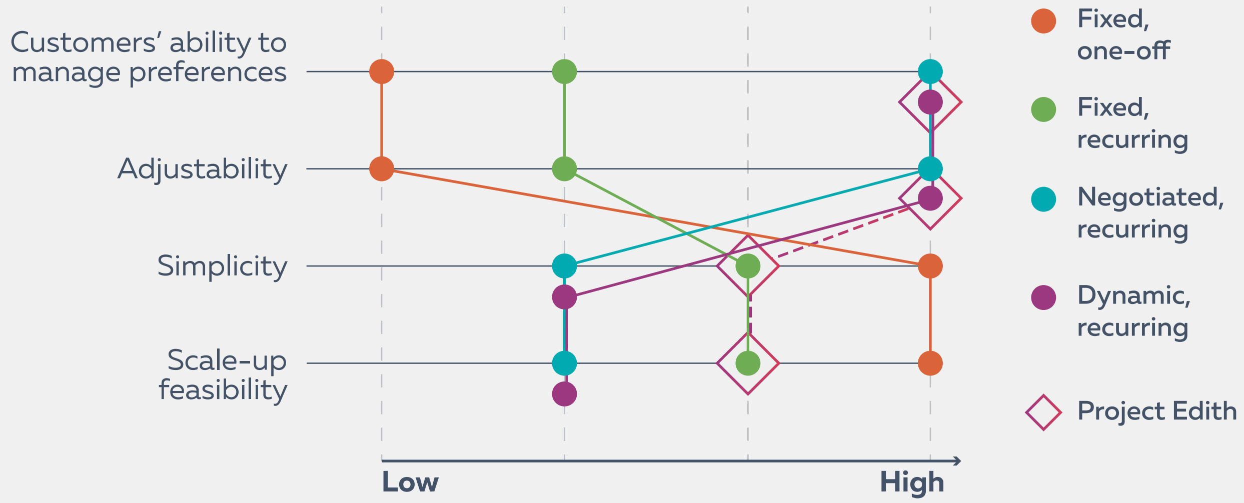
Table 5

Defining the payment type and recurrence

	DIMENSION	VARIATION 1	VARIATION 2	VARIATION 3
2	**Payment type** **The process to compute or settle upon the price that is eventually paid in return for the delivery of network support.**	**Fixed** A constant price that is contractually fixed and does not change for each contracting period. For example, the DSO sets the price per kWh of network support to always be $1.	**Dynamic** A variable price, whereby a new price is set centrally on a given time interval, for example every five-minutes. For example, the DSO sets the price per kWh of network support to be $1 in interval 1 and then increases this to $1.20 in interval 2.	**Negotiated** A variable price that is established through iterative negotiation between the DSO and the customer (or their agent). This takes place on a given time interval, for example every five-minutes, or per posted need.
	Payment recurrence **The frequency of payment.**	**One-off** A single lump-sum payment or credit.	**Recurring** A repeated instalment across the contract period. This can recur at different time intervals, for example annually or monthly.	

Figure 6

Assessing the type and frequency of payment against the performance measures



KEY OBSERVATIONS ABOUT THE PAYMENT TYPE AND RECURRENCE

The assessment presented in **Figure 6** is based on the following observations:

- Where prices are fixed, computing prices at the defined payment frequency (one-off, recurring) is simpler than for prices that vary.
- Where prices vary, computation is simpler for dynamic payments, which follow a 'price setting' arrangement, compared to the iteration required to negotiate pricing.
- While a fixed, one-off payment may be easy to scale from a simplicity point of view, it is unclear how large this payment would need to be to ensure that sufficient value is shared to support the customer agent's value proposition and encourage ongoing customer participation. As such, one-off payments may need to be accompanied by enforceable, binding contracts that guarantee a certain duration of participation.

WHAT DOES PROJECT EDITH DO?

Project Edith overcomes some of the challenges faced by dynamic pricing because it takes advantage of an extended billing system that manages all pricing structures. This is considered to be simpler and more scalable than an option that requires a separate reconciliation process (outside of the existing billing systems).

The dynamic pricing approach demonstrated through Project Edith continues the transition to more cost-reflective pricing for residential and small business customers that is underway in Australia. This leverages a path that DSOs in Australia have already been on for some time, continuing a build-up of existing capabilities to a range of more dynamic capabilities. Challenges with scale-up feasibility are therefore expected to persist in the short-term only.

Dimension 3
Firmness

POSITIONING THE VARIATIONS

There is considerable variety in the different levels of firmness that the case studies consider. For some case studies, multiple levels of firmness are used across the different services tested or demonstrated. This provides some certainty around the minimum amount of support that will be provided, through a high firmness solution, typically contracted in advance. Combining this with low and medium firmness solutions provides different levers that the DSO can pull across a range of time horizons, to respond to changing network and market conditions. The level of firmness for a given service will directly impact the risk of non-delivery. Non-delivery refers to the event in which a network support service is not delivered or the 'amount' of service delivered is insufficient to address the network constraint.

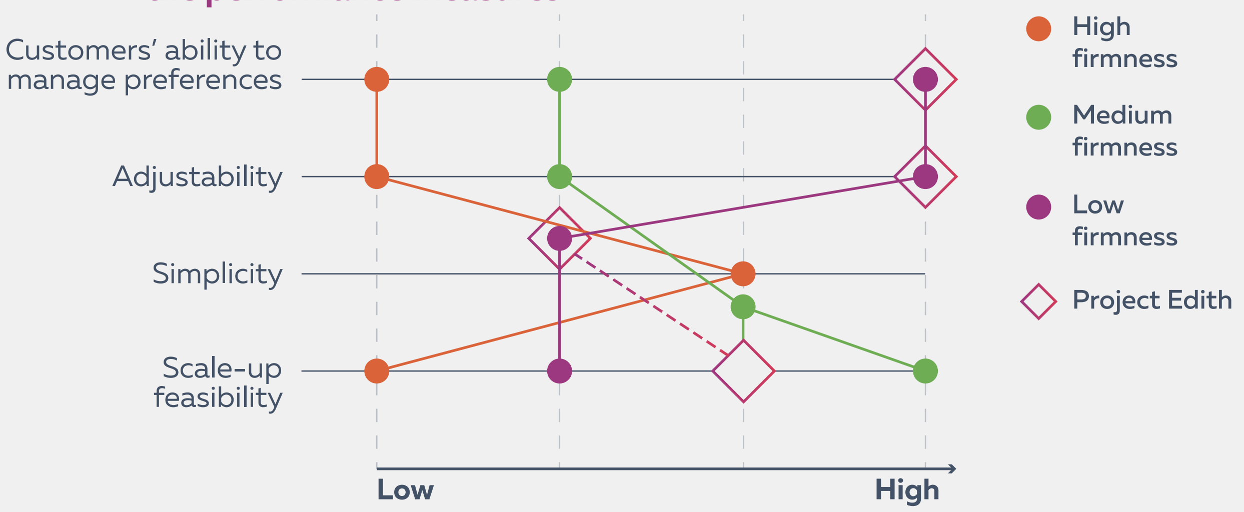
Table 6

Defining the different levels of firmness

	DIMENSION	VARIATION 1	VARIATION 2	VARIATION 3
3	**Firmness** **Indicates the certainty around the service delivery, where a high firmness service is very certain, and a low firmness service is uncertain.**	**Low** Uncertain availability and service delivery.	**Medium** Availability and service delivery is likely, but not guaranteed.	**High** Guaranteed availability and service delivery.

Figure 7

Assessing the levels of firmness against the performance measures



KEY OBSERVATIONS ABOUT THE FIRMNESS

Unlike other dimensions considered, firmness is unique in that there is no considerable range in simplicity across the variations – low, medium and high firmness. In theory, low firmness is simple. However, to counterbalance the likelihood that the customer response will be limited, DSOs emphasise the need to ensure modelling is as accurate as possible to minimise the risk of non-delivery. This requires a long learning curve, as the accuracy of current demand elasticity modelling practices is low.

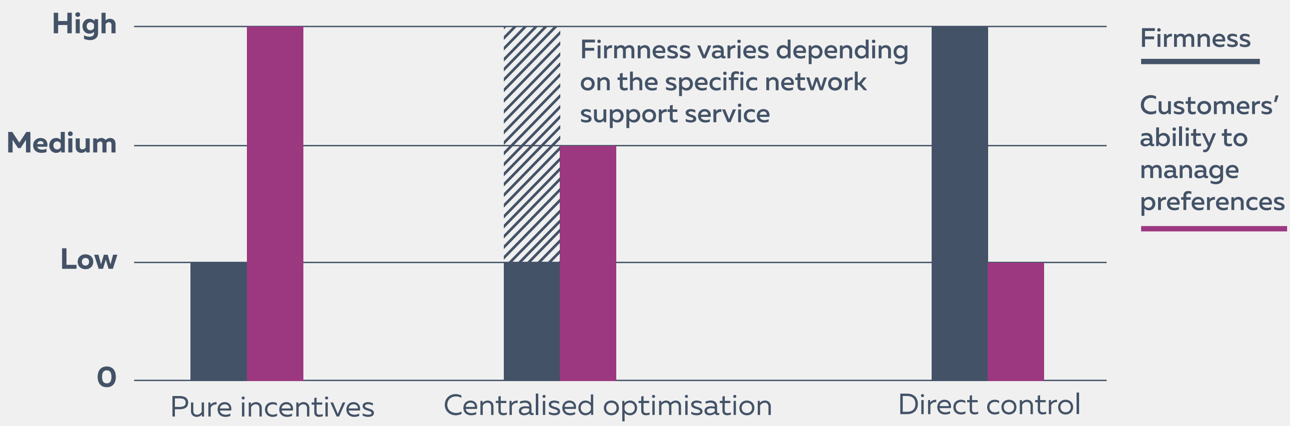
High firmness, on the other hand, requires robust contractual arrangements with firm obligations on delivery and administration of penalties for non-delivery. High firmness approaches also typically require larger payments for the same response, to guarantee participation. In some cases, high firmness options can also require that constraints are identified with sufficient certainty and anticipation or forewarning, which is both computationally intensive and requires robust modelling practices. If the constraint changes at short notice, a high firmness solution is 'locked-in' regardless of the changing conditions, thus limiting the customer agent's ability to manage CER participation and optimise on behalf of the customer.

WHAT DOES PROJECT EDITH DO?

To manage the uncertainty associated with the low firmness variation (from a network management perspective), Project Edith uses dynamic operating envelopes as 'guardrails' for CER to operate within – rather than requiring a firm response. The parallel use of DOEs improves the scalability of Project Edith, by providing CER with the maximum access to use the network to participate in markets while ensuring the network is used safely. Nevertheless, there will likely be cases where a high level of firmness and reliability of response is necessary. The dynamic pricing approach used in Project Edith can run in parallel to other approaches to network support. This is discussed further in **Section 5.3**.

There is an overarching trade-off between firmness and the customer's ability to manage their preferences. By limiting the customer's ability to manage their preferences, the customer agent is in turn also limited in their ability to respond to other market signals and access a greater value stack. The restrictiveness of firmness links back to the activation mechanism that is used (discussed in **Dimension 1 – Activation mechanism**), as illustrated in **Figure 8**. Limiting the customer's ability to manage their preferences could make scaling up difficult, as a barrier to customer acquisition. This is because customers might perceive this degree of control as an overreach of the network's authority and barrier to accessing additional value.

Figure 8 **Trade-off between firmness and customers' ability to manage their preferences, by activation mechanism**



Dimension 4
Pricing types

POSITIONING THE VARIATIONS

Most case studies analysed preference pricing that is on a per unit basis – to better reflect the anticipated and actual value of service delivery. In some cases, one case study may consider multiple pricing types, depending on the specific services that are being used.

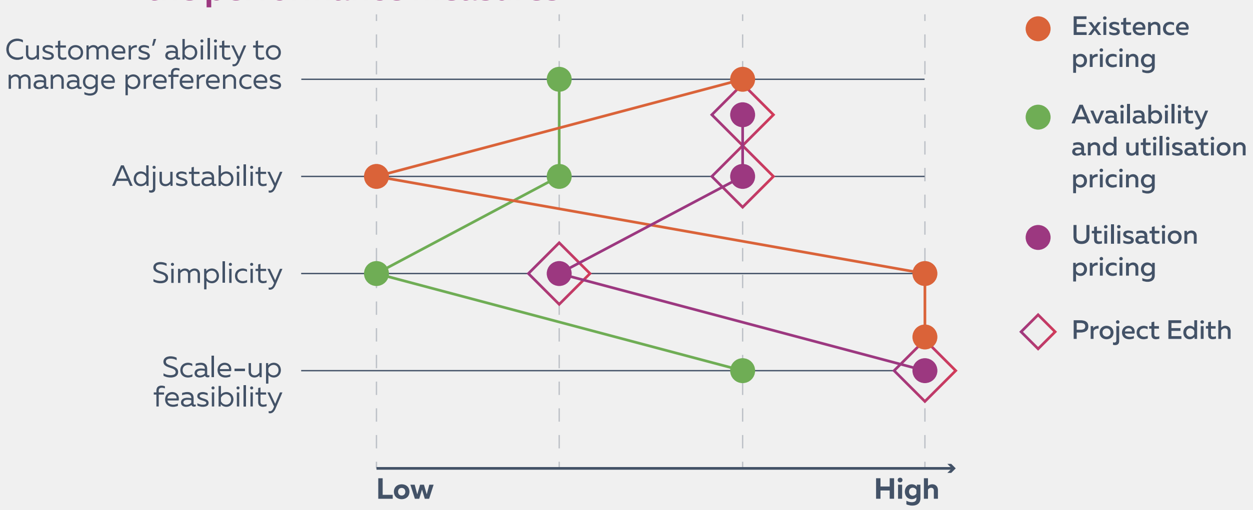
Table 7

Defining the types of pricing

	DIMENSION	VARIATION 1	VARIATION 2	VARIATION 3
4	**Pricing types** **Elements for which payment is received. These can be on a per unit or aggregated basis.**	**Existence** Also called capacity pricing. Payment reflects the value of participation as opposed to actual value of the network support provided.	**Availability and utilisation** Payment is made for both: **Availability** – being available to deliver during a particular timeframe (per kW/kVAr) **Utilisation** – the verified delivery of real/reactive power (per kWh/kVArh), if a service is activated / dispatch	**Utilisation** Payment is made for the verified delivery of real/reactive power or of service only.

Figure 9

Assessing the types of pricing against the performance measures



KEY OBSERVATIONS ABOUT THE PRICING TYPE

The assessment presented in **Figure 9** is based on the following observations:

- Existence pricing lowers the computation required. This is mainly because this option does not require any measurement and verification to validate payment. A drawback of existence pricing is that because it does not properly target the required support (as payment is decoupled from utilisation), overpayment may be necessary. This can result in higher costs for the DSO. Furthermore, existence pricing most likely requires an agreement to allow the DSO to control devices and/or require a given response to certain network conditions. This lowers the customer's ability to manage their preferences.
- Availability pricing should guarantee capacity, at least in theory, thus ensuring that network support is provided when required. If pricing both availability and utilisation results in more value being shared with customers and their agents, then scale-up should be easier. This is because offering more value encourages customer participation.
- However, a price on both availability and utilisation will often spread the value that would otherwise be offered for a utilisation only pricing option across two payments instead of one. A utilisation-only pricing option therefore typically results in stronger price signals.

5

What additional opportunities does the 'Project Edith approach' create?

Following on from the dimension-by-dimension comparison presented in **Section 4**, this section focuses on where Project Edith positions itself with respect to the four business model dimensions and the outcomes of that positioning.

More specifically, it explores the specific opportunities that Project Edith's positioning creates with respect to:

5.1 Removing barriers to flexibility participating in energy markets

5.2 Stronger price signals

5.3 Ensuring compatibility with other approaches to network support

5.4 Signalling emerging constraints

5.1

Removing barriers to flexibility participating in energy markets

When compared to a procurement approach, a pure incentives approach (in the Project Edith context, dynamic network pricing) minimises interference with market signals. This approach enables customer agents to stack multiple value streams, as explored in the section on **Dimension 1 – Activation mechanism**.

The primary objective of Project Edith and a dynamic pricing approach more generally is to remove the barriers to flexible CER participating in energy markets.

With dynamic pricing in place, it then becomes increasingly efficient to use the same solution to incentivise network support to address local network constraints, rather than using a separate system.

13 Customer energy resources with the ability to provide support by making temporary changes, when signalled, to the way energy is consumed, generated or stored.

5.2

Stronger price signals

While an approach that uses widespread signals that reflect the value of participation (as opposed to the actual value of network support provided) may be simpler to design and implement upfront, the value that can be shared with each participating customer is often diluted. Certain pricing types – such as existence, and availability and utilisation pricing (see **Dimension 4 – Pricing types**) – can lead to weaker price signals:

- In the absence of very granular and close to real-time forecasting, price signals are often spread across broad time windows and geographic areas.
- Weakened price signals lower the incentives for customers, or their agents, to participate and provide network support.

Project Edith is leveraging the DSO capability build-up that is already underway to demonstrate a more granular – in terms of both time and location – approach, taking a utilisation only pricing approach. This provides 'flexibility' on the distribution network side to adjust pricing as needed. By using more dynamic solutions, DSOs can better adapt to changing constraints and markets, as well as customer and customer agent needs or behaviours. Such changes could be spurred on by the introduction of more price-responsive technology or the development of new technical capabilities.

Through the approach tested in Project Edith, DSOs will be able to price network support through negative tariffs that 'pay' for the provision of services when and where it is needed. This creates a more efficient process for rewarding variable support for different locations and times.

5.3

Ensuring compatibility with other approaches to network support

While the approach tested in Project Edith minimises interference with market signals, dynamic pricing provides low visibility and firmness of the response from customers. As discussed in the section on Dimension 3 – Firmness, there will likely be cases where a high level of firmness and reliability of response is required. Where a such a firm response is required, an approach that places contractual obligations on delivery (such as through procurement) may be necessary [11]. For example, high firmness or reliability may be required where this is a single customer (or a few customers) providing the support. In other words, use cases where there is low or no diversification across customers.

5.4

Signalling emerging constraints

Dynamic pricing, as proposed through Project Edith, moves towards locational equity rather than equality. In other words, location-specific prices account for the future costs of providing electricity at each connection point. Responses to dynamic pricing can also help identify sections of the network where capacity is highly valued or where customers have a lower price elasticity. The data gathered from CER creates opportunities for DSOs to gain better awareness of the differences across customers, CER and network constraints at a more granular level and so better manage and plan for the network [8].

While dynamic pricing can be used to address specific forecasted constraints, it has the possibility for a broader use – even where there may not necessarily be a constraint yet.

This depends on how the pricing mechanism is designed and implemented, with respect to payment type and recurrence (see **Dimension 2 – Payment type and recurrence**). Dynamic and recurring prices can evolve over time by considering the generation and consumption evolution before a constraint is reached.

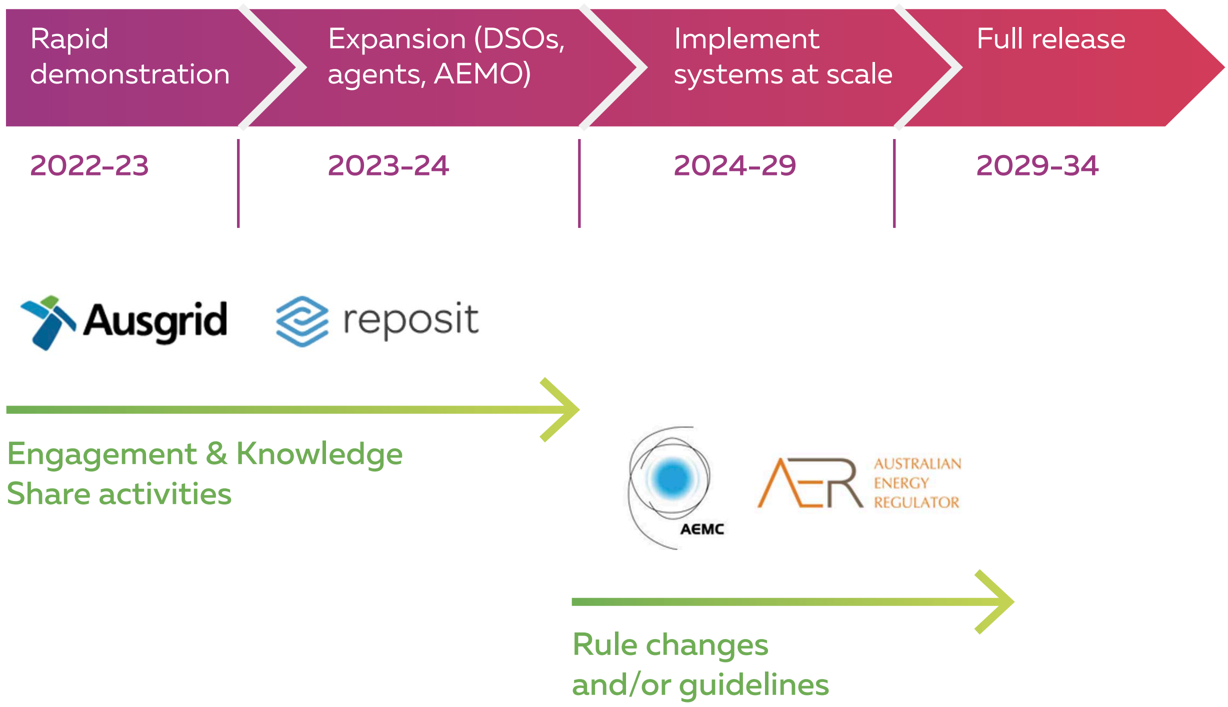
Pricing would then allow customers to respond in a way that can prevent a constraint from emerging at all. In other words, dynamic prices (as demonstrated through Project Edith) help 'forward signal' emerging constraints. This would also help signal to the DSO, customers, and other parties where there is a need to build more capacity.

What comes next for Project Edith?

Stage 1 of Project Edith is the initial testing of the concept with a single customer agent (Reposit) and single DSO (Ausgrid). This stage demonstrated an end-to-end, dynamic solution.

Following on from a successful completion of Stage 1, Project Edith is progressing with an extension to more customer agents, other DSOs in Australia, and then AEMO to further integrate virtual power plants (VPPs) into energy markets. These next stages are shown in **Figure 10**. The workplan for Project Edith has been structured such that findings from each stage inform the next steps. As such, the demonstration timeline may change.

Figure 10 Project Edith timeline



6

Network support: three areas for future investigation

Based on this study's comparison of current and emerging solutions, three main areas for future investigation were identified, as outlined below. These areas relate to how best to use and manage dynamic, flexible approaches to CER and network support.

This section suggests practical next steps to support the greater use of price-responsive CER for network support in Australia and facilitate the market integration of CER.

6.1

Investigate whether the choice for simple solutions is situational or structural

Most of the case studies examined in this study exhibit a tendency towards simplicity, at least during the initial testing phases. Simplicity refers to the ability to deliver network support without needing to go through additional processes, platforms, overheads and challenges.

While a simple solution can be the optimal one, simplicity can also inhibit value to the DSO, customer, or their agent. Simplicity can be attributable to the need to get a solution up-and-running as soon as possible to address immediate network challenges. Moreover, lack of internal capabilities, high costs of implementation and the immaturity of the CER market can make it a difficult environment to introduce more sophisticated solutions. Thus far, simplicity was perhaps required on the DSO side because the responses that customers could provide were simple. For example, by changing their air conditioner operating mode, without affecting their comfort to an unreasonable extent.

It is becoming easier for customer agents to provide network support while still managing customers' needs and preferences and sharing value. This is facilitated by increasing interaction between devices in the home and rises in the number of customer resources that can participate. This enables purely economic optimisation on the customer side, in response to an apparently complex dynamic pricing incentive structure, while still allowing the customer agent to retain a simple customer proposition.

Regardless of the underlying reasons, simplicity emerges as an initial success factor within the current market context – wherein more complex approaches have thus far been unable to deliver the anticipated value. What remains unclear, however, is whether scale will lead to a more practical and optimal way to implement more sophisticated solutions that have the potential to unlock more value for and from CER. Future work is needed to demonstrate whether – in a world where smart CER are abundant, capabilities are built on the DSO and customer/agent side, and the required processes are in place – a cost-benefit assessment will favour sophisticated solutions over 'simple' solutions.

6.2

Explore to what extent multiple approaches to network support could run in parallel

As demonstrated by the variety of approaches being tested in the UK and Australia, how best to value flexibility and use of CER for network support remains unknown. Each solution was designed to address a type of constraint that is specific to its local network, depending on characteristics like geography, CER type, or technical capabilities (on both the DSO and customer agent sides). Despite no single solution having emerged as being able to address the complete range of distribution network challenges thus far, Project Edith advances an approach that aims to be applicable to the wider network, and that, by the nature of its design, can be deployed to any distribution network, alongside other approaches to network support.

There is still a need to understand whether a single, 'one-size-fits-all' solution is possible, or if future needs will have to be met by multiple complementary solutions that run in parallel. For example, by using a combination of high and low firmness network support services addressing various constraints (as per Project EDGE) or dynamic network pricing and dynamic operating envelopes (as per Project Edith). The dynamic pricing approach used in Project Edith can also run in parallel to direct procurement, whereby bilateral arrangements for network support may still be used when needed (most likely for larger customers).

Taking into consideration the variety across customers in terms of size (residential, commercial, industrial) and the types of CER, and the different native and enabled capabilities they have installed, the most pragmatic option might be to combine multiple approaches to network support. One possible future could see dynamic pricing managing most of the network's needs, through targeted incentives for controllable, discretionary resources such as home batteries. This could be complemented by a minimal, and targeted, use of direct bilateral arrangements or a simplified marketplace arrangement where firm responses are required (most likely to be procured from large customers). Where multiple approaches are used, ensuring that there is not excessive complexity and cost when combining approaches will be crucial.

Each of the different approaches provides different levels of firmness, 'flexibility' to respond at different time horizons and value for flexibility, which can be useful in the overall network management strategy.

6.3

Quantify the value that new approaches to managing network constraints unlock and assess how this is shared with customers

New approaches to managing network constraints refer to approaches that can be adapted to reflect the actual network conditions. There is considerable uncertainty around the value that these approaches might unlock, especially if solutions were to operate at scale. The analyses around the benefits and costs that DSOs, customer agents and customers might be exposed to are at varying stages of maturity. Thus far, implementations have focused mostly on demonstrating technical feasibility.

The quantification of costs and benefits has been identified as an important next step for scaling up new approaches to managing network constraints. For many of the case studies assessed, this has not yet been considered. However, regardless of the financial value that network support might unlock, if solutions are to succeed at scale, ensuring that customers can continue to both manage their own preferences and realise tangible benefits – without necessarily being exposed to the complexities happening in the background – will be key to scale-up.

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Appendix A

Delivery model dimensions considered as part of this study

Dimension 5

Type of CER

POSITIONING THE VARIATIONS

CER is enabling households to participate in an increasingly two-way energy market, as outlined in **Section 1.1**. However, the extent to which residential customers can participate will depend on the specific capabilities of their energy resources.

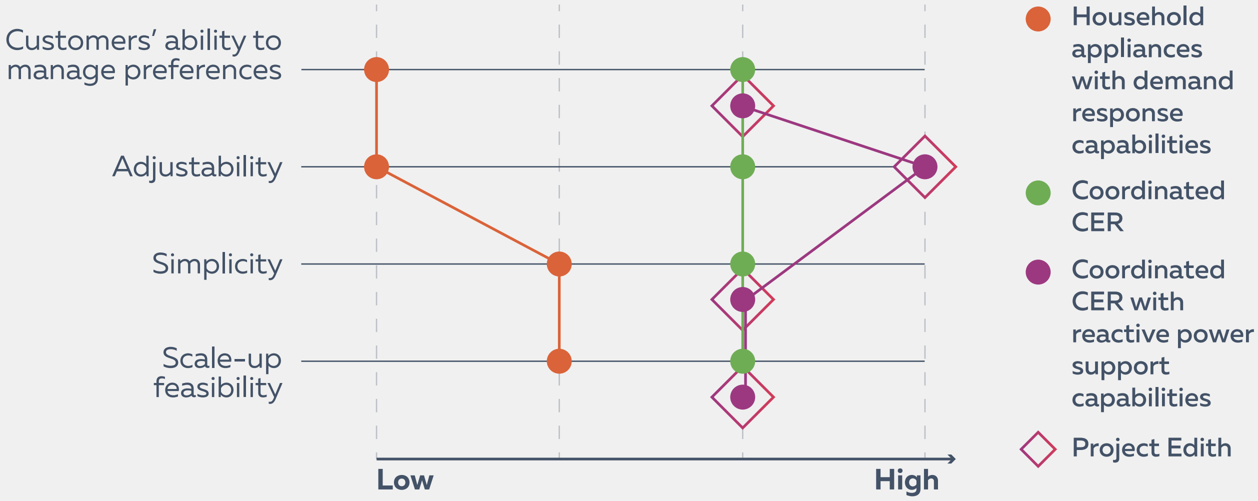
Table 8

Defining the different types of CER

	DIMENSION	VARIATION 1	VARIATION 2	VARIATION 3
5	**Type of CER** **The capabilities and sophistication of the customer resources.**	**Household appliances with demand response capabilities** Commonly referred to as controllable loads, including pool pumps and air conditioners. These can be used for simple demand response services, such as peak-shaving or emergency shut off.	**Coordinated CER** Resources with some energy management capabilities. These capabilities can either be native or enabled through a home energy management system, or HEMS, gateway device. CER are coordinated to optimise performance.	**Coordinated CER with reactive power support capabilities** Advanced resources with a range of smart capabilities, including the ability to provide reactive power support.

Figure 11

Assessing the different types of CER against the performance measures



Some types of network support services have very specific and advanced requirements, thereby limiting the number of CER that can provide that service – at least for the time being, while the market penetration of more advanced CER remains relatively low. While moving from one variation shown in **Table 8** to the next adds more sophisticated capabilities, it does not preclude the initial capabilities. For example, coordinated CER (Variation 2) can still have the demand response capabilities described under Variation 1.

Most of the case studies assessed as part of this study have targeted the middle of the range CER. Only two examples target the newer resources with more advanced capabilities. As discussed earlier in this report, the market landscape will naturally evolve towards one with more Variation 3 energy resources. The approach demonstrated in Project Edith takes advantage of these emerging, more advanced capabilities to future-proof the approach and make it more scalable.

KEY OBSERVATIONS ABOUT THE TYPE OF CER

Figure 11 shows how smarter CER – presented as Variations 2 and 3 in **Table 8** – offer customers the possibility to better manage their electricity consumption and generation towards maximising their benefits. Because these resources are equipped with more sophisticated capabilities and allow for interoperability (by using standardised communication protocols, which household appliances typically do not do), it is simpler for customer agents to integrate with and coordinate these resources. This facilitates the market integration of these CER. Improved market integration provides customer agents with greater access to the wholesale and services markets.

On the DSO side, leveraging the deployment of coordinated CER with reactive power support capabilities ensures that both thermal and voltage constraints can be easily managed (see **Dimension 6 – Type of service**).

Dimension 6

Type of service

POSITIONING THE VARIATIONS

Of the case studies reviewed, most have tested or scaled up demand management services only. Only two consider both demand and voltage management, of which one is Project Edith. This could in part be driven by the fact that three of the eight case studies take place in the United Kingdom, where managing thermal constraints is a more immediate issue given the relatively low uptake of rooftop solar compared to Australia.

Furthermore, voltage responses are provided by AS4777.2 compliant inverters[15]. This provides some initial network support and could lessen the need for further voltage management solutions. Despite the added complexity that voltage management presents, this use case makes sense in Australia as both thermal and voltage constraints pose immediate challenges for the distribution network.

14 The AS4777.2 inverter requirements specify the expected performance capabilities and behaviours of inverters at low voltages (for example, those installed in households) [17].

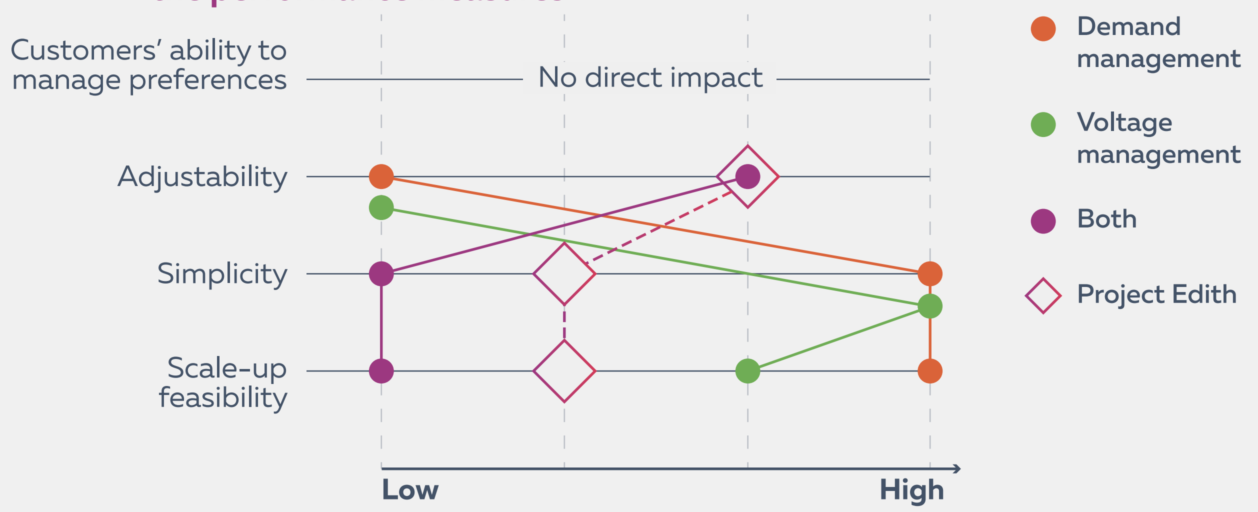
Table 9

Defining the different types of network support services

	DIMENSION	VARIATION 1	VARIATION 2	VARIATION 3
6	**Type of service** **The network support that the customer, or their agent, provides.**	**Demand management** Power consumption or generation is ramped up or down, to either raise or lower the demand for real or reactive power.	**Voltage management** Reactive power is injected to or absorbed from the grid to stabilise the local voltage levels.	**Both**

Figure 12

Assessing the different service types against the performance measures



KEY OBSERVATIONS ABOUT THE TYPE OF SERVICE

The assessment presented in **Figure 12** is based on the following observations:

- Demand management is intrinsically simpler than voltage management. With voltage management, the ability to set up this type of service depends on the DSO's visibility at the local level and the granularity thereof. While this is where voltage constraints typically emerge (as a highly localised issue), the LV network is not a part of the network that DSOs have typically had to monitor. Note that an uplift in these monitoring capabilities is envisioned to take place as the rollout of DOEs progresses across Australia.
- In the Australian context, voltage management services are of relevance given the suitability to respond to solar export related constraints. Where a DSO has the capability to implement both types of services, this offers better coverage of the different types of constraints (thermal and voltage). However, it is both complex to implement and manage running two types of service in parallel, for DSOs and customer agents.
- There are also complex requirements for CER to participate in voltage management services, as this service requires CER with specific reactive power capabilities. This limits scalability, linked to the relatively small (but rising) number of CER with the required capabilities.
- As the deployment of CER with reactive power capabilities increases, this is expected to result in a reduction of network augmentation expenditure required to address voltage constraints. This is because these resources present DSOs with a potentially lower cost approach to voltage management.

WHAT DOES PROJECT EDITH DO?

Project Edith addresses both voltage and demand management within the same dynamic pricing system. This approach is expected to be simpler than an approach that uses parallel systems to manage each service independently.

Dimension 7

Geographic resolution of the signal

POSITIONING THE VARIATIONS

The geographic resolution of the signal ranges from widespread, whole of network signals down to signals at the individual connection point, as defined in **Table 10**. For some case studies, including Project Edith, the resolution that is currently being tested may not necessarily reflect the more granular target state. The evolution to the target state is expected to occur as DSOs continue to evolve their modelling and forecasting capabilities, to identify constraints with increasing granularity. This uplift is expected to take place as the rollout of DOEs progresses.

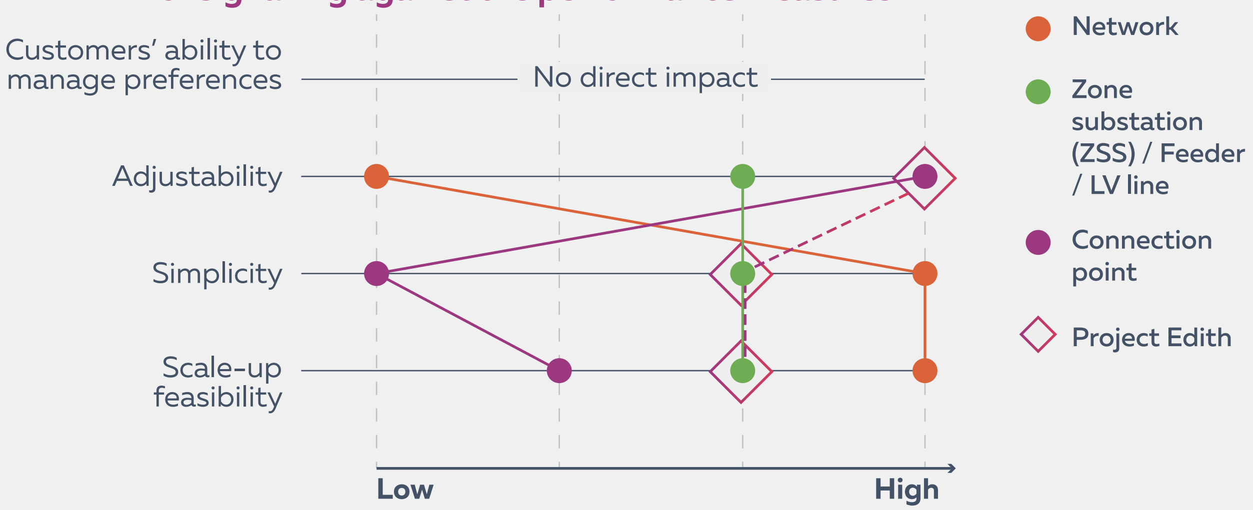
Table 10

Defining the geographic resolutions to which signals are sent

	DIMENSION	VARIATION 1	VARIATION 2	VARIATION 3
7	**Geographic resolution of the signal** The location on the network to which the signal is sent	**Network** Widespread signal, reaching all active/ participating customers on the network.	**Zone substation (ZSS) / Feeder / LV line** Location-specific signal per network area, targeting a given subgroup of customers within that area.	**Connection point** Unique signal per customer connection, with a specific instruction or incentive communicated to each customer

Figure 13

Assessing the different geographic resolutions for signalling against the performance measures



KEY OBSERVATIONS ABOUT THE GEOGRAPHIC RESOLUTION OF THE SIGNAL

The assessment presented in **Figure 13** is based on the following key observations:

- As the geographic resolution becomes more granular, the signalling process becomes less simple. This is because it is more computationally intensive to map locations against identified constraints and requires forecasting capabilities that some DSOs do not yet have in place. Note, however, that the representation in **Figure 13** assumes that the necessary modelling and forecasting capabilities will be developed as the rollout of DOEs progresses.
- When it comes to signalling, granularity adds to the forecasting requirements and baselining complexity. However, this added granularity provides the DSO with the ability to align incentives or service activation with the specific network constraint. Granularity also provides the DSO with more 'flexibility' to respond to emerging or changing constraints.
- Conversely, network-wide signals result in less targeted services and in turn, responses. Network signals also result in needing to spread value more widely, which weakens the price signal and therefore may not be as effective in eliciting the desired response.

WHAT DOES PROJECT EDITH DO?

Project Edith adopts a more targeted price signal. While the default setting will be one that is less granular than at the connection point, the approach preserves the ability to become more granular (for example, down to the connection point level) when needed. By doing so, the approach avoids overpaying for more network support than may be needed, because it can adjust the signal to only target constrained areas. As a result, investments in network augmentation can be avoided, lowering costs for customers (including those who are not CER owners). Furthermore, this avoids unnecessary computation so long as constraints are sufficiently addressed and managed.

Dimension 8

Time scale for setting the price on the provision of network support

POSITIONING THE VARIATIONS

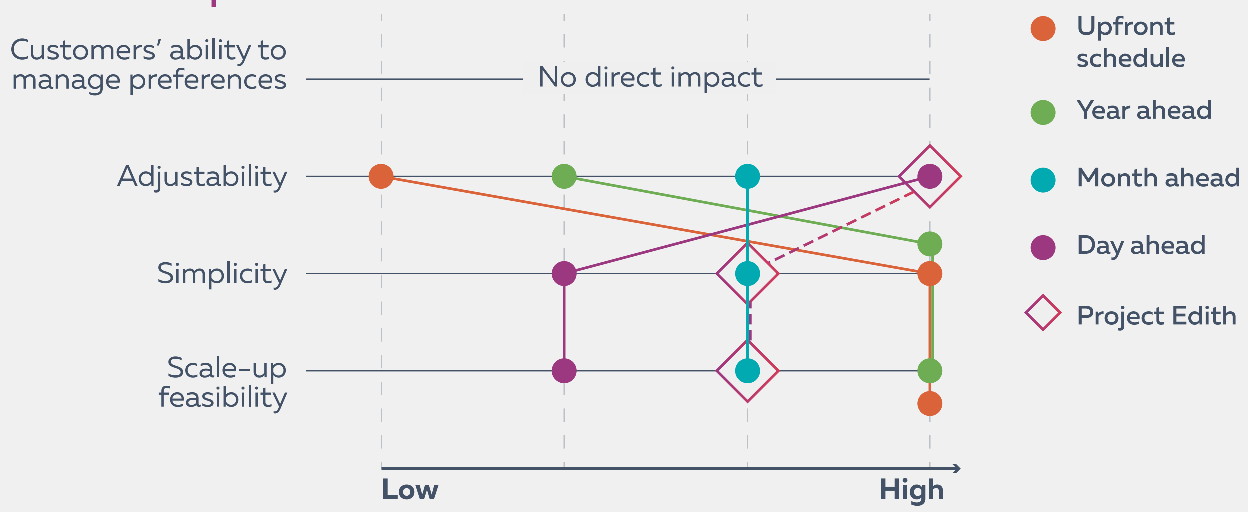
Table 11

Defining the time scale for setting the price (this section) and for signalling network support (next section)

	DIMENSIONS 8 AND 9	VARIATION 1	VARIATION 2	VARIATION 3
8 – 9	**Time scale (for setting the price, signalling network support)** **The amount of time in advance that specific characteristics of the solution or service provision are defined.**	**Upfront** Agreed upon at contract execution.	**Year ahead / Seasonal / Month ahead** Communicated after contract execution but with significant lead time.	**Day ahead / Intra-day** Short notice period communicated 24 hours in advance or less.

Figure 14

Assessing the time scales for price setting against the performance measures



KEY OBSERVATIONS ABOUT THE TIME SCALE FOR SETTING THE PRICE

The assessment presented in **Figure 14** is based on the following observations:

- When assessing the time scales for setting the price on the provision of network support (this dimension) and signalling network support (see **Dimension 9 – Time scale for signalling network support**), conflicting forces emerge. It can be argued that having a longer time scale with notice provided further in advance gives the customer and their agent the ability to prepare and plan. However, longer time scales are typically associated with enforcement mechanisms. These are put in place by the DSO to ensure the delivery of network support (when the time comes), as mentioned in **Section 4** of this report. Hence, the time scale for setting the price and signalling network support has no clear impact on the customers' ability to manage their preferences in one direction or the other. Furthermore, any such impact will depend on the individual customer's preferences – some will prefer to have the schedule in advance while others may prefer the day ahead option.
- Simplicity decreases towards shorter time scales for setting the price, as recurring calculation and adjustment of the price is needed. However, while less simple, shorter time scales like those, used in Project Edith, have the advantage of providing the DSO with greater 'flexibility' to adjust and respond to changing market conditions. This facilitates more value being shared with customers.
- In terms of scale-up feasibility, not only is an upfront schedule less computationally intensive but it also provides certainty of dispatch for customer agents. This can provide foresight for optimising CER responses and help bankability. When setting the price so far in advance, however, the value offered for the provision of network support is likely to be undermined. This is due to the inability to adjust the request if the constraint changes or disappears, resulting in higher overall costs.

WHAT DOES PROJECT EDITH DO?

Project Edith leverages existing price setting processes and adapts these to a new frequency (day ahead). By building on existing capabilities, Project Edith demonstrates an approach to a day ahead time scale for pricing that is simpler and more scalable. This same reasoning applies for **Dimension 9 – Time scale for signalling network support**.

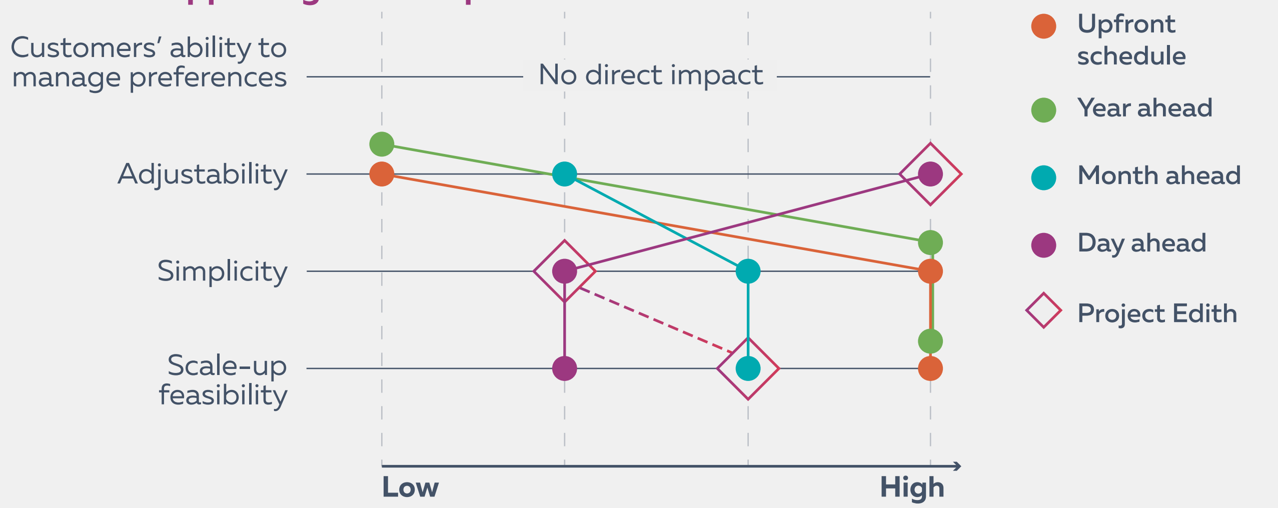
Dimension 9

Time scale for signalling network support

POSITIONING THE VARIATIONS

Figure 15

Assessing the time scales for signalling network support against the performance measures



KEY OBSERVATIONS ABOUT THE TIME SCALE FOR SIGNALLING NETWORK SUPPORT

The assessment presented in **Figure 15** is based on the following key observations:

- As outlined in the discussion of **Dimension 8 – Time scale for setting the price on the provision of network support**, time scale for signalling network support has no clear impact on the customer's ability to manage their preferences. This is because several conflicting forces emerge.
- The notice period directly impacts the DSO's ability to address emerging and changing constraints. While upfront schedules may incur lower overheads, offer the DSO some initial simplicity and be likely to be easier to scale, schedules are often a best guess of how the future constraint will look. This results in higher overall costs.
- In all cases, the DSO's ability to address the identified constraint is highly dependent on the forecasting accuracy and visibility. This is still true moving towards day ahead time scales, as near-real-time modelling techniques also risk miscalculating the level of support required. As the implementation of DOEs advances, the associated improvements in forecasting accuracy and LV visibility will facilitate the identification of network constraints.

Dimension 10

Forecasting approach

POSITIONING THE VARIATIONS

While some of the stakeholders consulted identified optimal power flow modelling as a key capability to develop, most use heuristics-based approaches for the time being. By considering a range of external data inputs, heuristics offer considerable improvements in accuracy compared to a historical approximation approach. This approach remains simpler than power flow modelling, as illustrated in **Figure 16**.

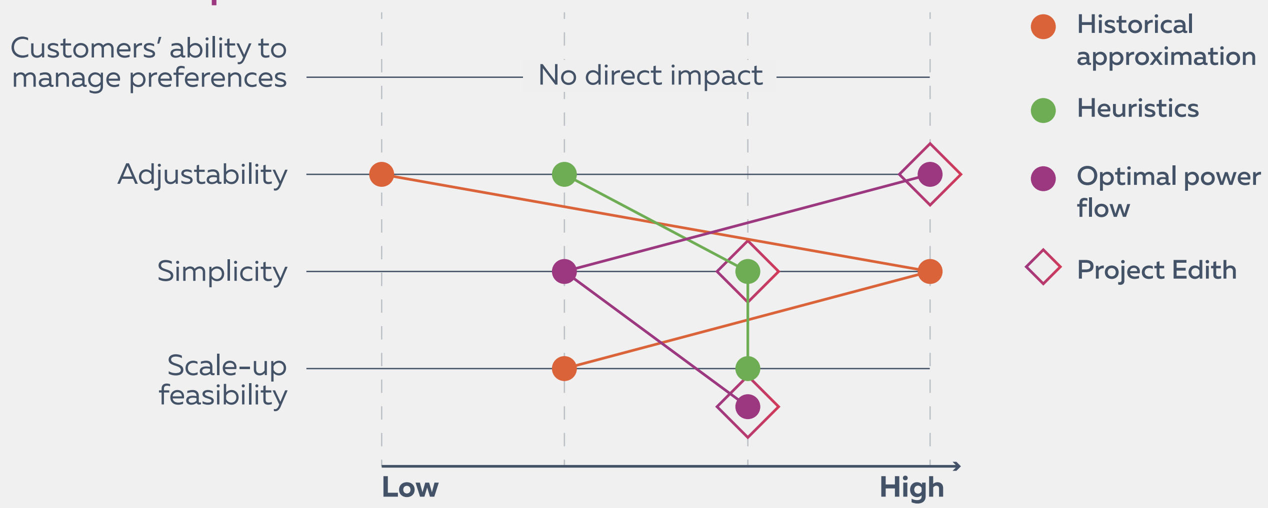
Table 12

Defining the different forecasting approaches

	DIMENSION	VARIATION 1	VARIATION 2	VARIATION 3
10	**Forecasting approach** **Techniques used to identify future constraints and/or model customer behaviour**	**Historical approximation** Extrapolation of the trend, using historical data to predict future behaviour or occurrences. Considers a limited set, if any, of external data inputs.	**Heuristics** Data-driven technique that relies on a range ofexternal data inputs to drive forecasts.	**Optimal power flow** Computation to find the Optimal Power Flow solution for the distribution network. Optimisation is based a specified objective function and a set of defined constraints.

Figure 16

Assessing the forecasting approaches against the performance measures



KEY OBSERVATIONS ABOUT THE FORECASTING APPROACH

The assessment presented in **Figure 16** is based on the following key observations:

- Introducing external variables reduces the simplicity of the forecasting approach. This is true for both a heuristics-based and optimal power flow modelling approach. As each modelling approach becomes less simple, the overheads rise. Overheads are linked to the initial setup cost as a DSO improves its forecasting capabilities plus the ongoing computational intensity. Assuming the future set of capabilities required to rollout DOEs, the incremental burden associated with more advanced modelling approaches is lowered.
- While more sophisticated approaches may appear to be less simple upfront, incorporating additional variables beyond historical data improves forecasting accuracy. More accurate forecasts improve the DSO's ability to target and signal specific, highly localised constraints. This reduces the volumes of 'overpayment' to customers (in return for network support) and helps to avoid unnecessary network investments. Project Edith builds on improved forecasting capabilities that are emerging, to optimise the identification of network constraint.
- For a heuristics-based approach, the additional accuracy that can be achieved will depend on the number and type of external variables that are considered as well as how well those are correlated with supply and demand on a given network.

WHAT DOES PROJECT EDITH DO?

Project Edith takes advantage of existing capabilities (heuristics-based modelling approaches). This means that it can already be implemented today and does not need optimal power flow modelling to work at scale. Project Edith has also been designed to be compatible with that future state and take advantage of the more sophisticated modelling tools and enhanced capabilities as these become available.

Appendix B

Case study factsheets

SSEN / ENWL

Transition

ORGANISATIONS INVOLVED	DSO SSEN | Aggregators Multiple, including Nuvve (focused on EV charge management)		
APPROACH TO NETWORK SUPPORT	**Direct procurement (bilateral arrangement)**	Dynamic tariffs	
CONSTRAINTS ADDRESSED	**Thermal**	Voltage	
CUSTOMERS PARTICIPATING	**C&I**	Residential	
TYPE OF CER	Community based batteries, rooftop solar, V2G EV chargers[1]		
IMPLEMENTATION PHASE	Pilot	**Trial**	Commercial roll-out

Overview

APPROACH

The first set of trials ran for 17 weeks, with 69 events, 18 assets. The trials have predominately tested the ability of an asset to deliver a set amount of flexibility at a set time. There were 3 trial periods that lasted until February 2023. We focus on the first trial period that went from November 2021 to February 2022[2]. See on the right, the scenarios and services tested.

The auctions were run and tested on two marketplace platforms:

1. A Neutral Market Facilitator (NMF): marketplace between the DSO and market participants.
2. Piclo (independent marketplace)

The following conditions applied to the initial round of trials:

1. **SPM auctions focused on three network areas** where potential market participants indicated they had available CERs.
2. The capacity requested through auctions for SPM was **restricted** to that of available CERs.
3. Two types of CER expressed an interest in participating in auctions: a community battery and multiple Vehicle to Grid (V2G) chargers managed by an aggregator.
4. Auction delivery periods were from 0.5 hours to 2 hours, with the full period 15:00 – 19:00.

1 The V2G Chargers are across 3 locations; residential (6kW; unused to a variety of technical issues); commercial (36kW); and educational (36kW).
2 Transition & Project LEO, Market Trials Report (Period 1), April 2022, Project LEO and TRANSITION Market Trials Report (Period 1) - Project LEO (project-leo.co.uk).

The participants were able to choose a **baselining** method (or both[3]) depending on what suited them best[4]:

A Historic Baseline which uses past meter data with an assumption that the participant's generation or consumption (if no flexibility service was being provided) would be the same as on other previous comparable days and time.

OR

A Nominated Baseline which forecasts looking ahead at the period of time the flexibility service will be needed. What the participant's generation or consumption will be at that time if no flexibility service is being provided.

CUSTOMER REWARDS & INVOLVEMENT

The prices paid for flexibility have been computed on a Willingness to Pay (WTP) and Willingness to Accept (WTA) basis, with a ceiling price of £300/MWh split into an availability and utilisation price.

3 There is an option to **use both of these methods** by providing both historical data and forecast. In this case, participants are paid for whichever results in the greater amount of flexibility delivered.
4 SSEN, Baselining for the trials, 2022.
5 There was no physical testing of the DSO-enabled services during the trials.

SERVICES AND SCENARIOS PROCURED THROUGH THE PICLO PLATFORM

	DSO-PROCURED	DSO-ENABLED[5]	
	SUSTAIN PEAK MANAGEMENT (SPM)	EXCEEDING MAXIMUM EXPORT CAPACITY	EXCEEDING MAXIMUM IMPORT CAPACITY
Description	**Demand down, generation up service.** Market participants deliver flexibility during **peak demand periods** – to reduce load on critical assets (such as a transformer) forecast to overload due to excess demand. This service is delivered by CER that can generate (or discharge) power at given times, e.g., a battery, or demand response.	Two market participants in a network area with **limited (or no) spare export capacity** trade a portion of their **export** capacity for an agreed period, without affecting the network capacity. The Buyer can increase their export level, but the Seller must reduce their export level.	Two market participants in a network area with **limited (or no) spare import capacity** trade a portion of their **import** capacity for an agreed period without affecting the network capacity. The Buyer can increase their import level, but the Seller must reduce their import level.
Timing	Procurement is at season-ahead, week-ahead and day-ahead with at least 12 hours' prior notice for delivery.	Trading is week-ahead with the service available as specified in the trade.	Trading is week-ahead with the service available as specified in the trade.

Benefits, Costs/Challenges and Scalability

BENEFITS

Technology

- Using the Historic and/or Nominated baselining methodologies was accurate on the V2G and battery CER that participated in the trial.
- The NMF proved that multiple platforms could be used as customer interface but only one setting the auctions[6].
- Using reliable weather data as a forecasting input is shown to drive quality of the forecasts.

Customer acquisition

- **Carbon savings** and organisations' **commitment to Net Zero** are key areas of interest from the participants' point of view.

Markets

- Benefits will depend **on large CAPEX being deferred and low flexibility requirement.** The lower the reinforcement cost and the greater the Flexibility need, the lower the benefit will be for the market participants.

COSTS/CHALLENGES

Technology

- **Unpredictable behaviour of the EV** users resulted in high unavailability. The prices paid for SPM availability hence varied between CER types.
- There was an issue with the application of the **baseline** methodologies to V2G and similar new CERs.

→ CERs that have a predictable pattern of usage or sufficient historic data can reduce errors in the baseline, e.g., a battery co-located with solar PV that has a regular charge / discharge cycle will be easier to baseline than new EV chargers being used for flexibility due to unknown vehicle patterns.

→ CERs that need pre-conditioning may breach the baselining methodology, e.g., a battery that needs to charge between providing two different services.

→ CERs that already deliver a benefit, e.g., charge management, will struggle to prove delivery of a service, even though their behaviour contributes to reducing demand; this loss of stacking benefit may harm the provision of flexibility.

Customer acquisition

- **Lack of knowledge** about flexibility and the wider electricity industry.
- **Lack of skilled resources** within potential market participants was identified as a major and ongoing barrier to participation.
- Financial benefits of participation in trials were low and participants **were largely driven by non-financial benefits** (environmental, learning).
- Non-traditional market participants (e.g., local authorities, charities) rarely had the time or resources to understand flexibility services and flexibility markets. **The contractual arrangements are too complex and costly** to review for the level of flexibility involved.

Markets

- The SPM auctions having only two types of CER (EV and battery) resulted in **low liquidity** and the need for a wider variety of CER types and aggregators.

SCALABILITY

Technology

- The baselining methodology was successful but would need to be **tailored to each CER type.**
- **Greater automation** across end-to-end processes and a more userfriendly platform would be required to scale up.

Customer acquisition

- **Non-traditional market participants need to be assisted** with knowledge sharing and consideration of routes to markets, services and CERs in a summarised and easily digestible format.
- Need to review the prices for DSO-procured services and **adequately quantify the benefits** of participation.

Markets

- Need to increase the number of market participants and range of CER types to participate in future trial periods to **provide greater market liquidity** across a wider range of services and additional data for analysis.

6 Piclo used as customer interface. Transition & Project LEO, Market Trials Report (Period 1), April 2022, p.5.

UKPN

Piclo Flex

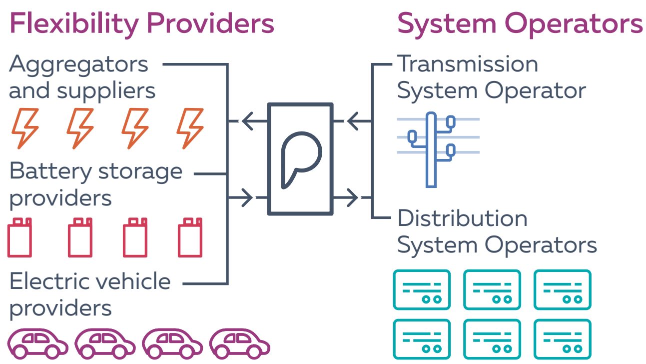
ORGANISATIONS INVOLVED	DSO Multiple, however this factsheet focuses on UK Power Networks | TSOs | Flexibility providers Multiple aggregators, individual customers with more than 10kW flexible capacity[1]		
APPROACH TO NETWORK SUPPORT	**Direct procurement**	Dynamic tariffs	
CONSTRAINTS ADDRESSED	**Thermal**	Voltage	
CUSTOMERS PARTICIPATING	**C&I**	**Residential**	
TYPE OF CER	Storage, EVs, Generators, Demand-side response (DSR)		
IMPLEMENTATION PHASE	Pilot	Trial	**Commercial roll-out**

Overview

APPROACH

Piclo Flex is an independent marketplace for trading flexibility online. The platform leverages digital technology to provide market visibility, asset qualification services and online auctions. The platform takes the process up to identifying the available providers, however contracting and dispatch is not yet integrated (DSOs continue these processes outside of the platform).

The model means that even small-scale flexibility providers can access the same market opportunities as larger assets or aggregated portfolios, regardless of their size (UKPN implements a 10kW minimum capacity threshold).



SERVICES AND SCENARIOS PROCURED THROUGH THE PICLO PLATFORM

	SECURE[2]	DYNAMIC[2]	SUSTAIN[2]
Example use case	Increase generation or decrease demand to reduce peak loads on High Voltage substations.	Increase generation or decrease demand to meet a variety of network needs, such as supplementing Secure or managing outages.	Increase generation or decrease demand to reduce peak loads on Low Voltage (LV) substations. Sustain is the primary Flexibility Service being procured for the Low Voltage zones.
Pricing	Flex providers are paid for their availability (£/MW/h) and for utilisation (£/MWh).	Flex providers are paid for utilisation (£/MWh) at a price set by the flex provider.	Flex providers are paid a fixed £/MW service fee.
Timing[3]	The minimum (aggregated) threshold for participation in Secure is 10kW and flex providers commit to deliver flexibility over 6 months ahead (at contract). Secure uses real-time dispatch.	There are no service windows, and it is optional for flex providers to accept dispatch instructions. Dynamic uses real-time dispatch.	The minimum (aggregated) threshold for participation is 10kW and flex providers commit to deliver flexibility 1 month ahead (with an option for 1 week ahead). Sustain uses scheduled dispatch.

1 Nationally rolled out platform which multiple DSOs/TSOs/flexibility providers are invited to participate in.
2 Piclo, Case Study, July 2020

Benefits, Costs/Challenges and Scalability

BENEFITS

Technology[4]

- The procurement process was enhanced to a more dynamic one that is **more electronic and automatic,** enabling customers to be self-serving and less reliant on the DNO.
- Administration and transaction **costs savings** for both the DSO and the flexibility provider.

Customer acquisition

- Flexibility providers can be **recruited regardless of size.**
- Having **visibility** on areas that are currently or likely to become constraint management areas incentivises providers with assets in those areas to participate.
- The platform is attractive if flexibility providers **can earn an income** to supplement or replace government incentives to promote the uptake of renewable and CER.

COSTS/CHALLENGES

Technology

- There is a lack of support for dispatch/settlement.
- The platform is not yet integrated to other DNO systems.
- There is a lack of coordination with national system operators. Greater focus is required from DNOs in keeping **a shared vision and standardised products** to ensure participation and swift operations.

Customer acquisition

- **Lack of standards** across DNOs and ESO (national system operator).
- Long- term procurement **doesn't suit all flexibility providers,** particularly storage and demand response CER.
- Flexibility providers are often put off by the manual processes involved. **There is a need for more automation and APIs.**
- Lack of customer knowledge about the markets and ability to afford CER assets, such as EV, remains a challenge to participation and to ensure that benefits are drawn for all electricity players.

SCALABILITY

The Piclo platform has been commercially rolled out and is in use by multiple DNSPs in the UK. UKPN's priorities for development are the following[3]:

- **Significantly increasing the participation of flexibility.**
- **Coordinating better with the ESO**[4]**.**

→ There are clear system-wide benefits to better coordination, as well as individually to ESO, DSOs and FSPs[5] – both in avoiding operational conflicts and in maximising utilisation (and commercial return) of each flexible asset.

- **Establishing a trusted flexibility market.**

→ Need to demonstrate that the DSO can make unbiased decision between flexibility and network solutions, through a fair and efficient application of market rules.

→ Simpler processes and greater automation as well as creating data interfaces that facilitate interactions between market participants.

3 To better align with closer to real-time procurement, wholesale market and ESO opportunities, some changes are expected to be made to the timing aspect of the services procured.
4 Piclo Case Study, July 2020;
5 Piclo, Energy on Trial, 2019;
6 Piclo, Flexibility and Visibility, 2019;
7 UKPN, Consultation: A step change in local flexibility, 2022;
8 Electricity System Operator; Flexibility Service Providers

National Grid

Sustain-H

ORGANISATIONS INVOLVED	National Grid | Aggregators Ecotricity, EDF Energy, Octopus Energy, Kaluza, Stemy Energy, ev.energy, myenergi[1]		
APPROACH TO NETWORK SUPPORT	**Direct procurement (bilateral arrangement)**	Dynamic tariffs	
CONSTRAINTS ADDRESSED	**Thermal**	Voltage	
CUSTOMERS PARTICIPATING	C&I	**Residential**	
TYPE OF CER	EV, Heat Pump, Battery		
IMPLEMENTATION PHASE	Pilot	**Trial**	Commercial roll-out

Overview

APPROACH

Sustain-H is a scheduled 'drop-to' service.

- Flexibility Providers deliver a **pre-agreed change in import or export (kW)** over a **defined period of time.**
- Flexibility Providers reduce demand to a level at or below a **pre-agreed Target** Demand and hold this for a **4-hour window.**

Contracted for fixed periods

- The service is **contracted seasonally for 6 months** in that season.
- Homes deliver the service for the **defined 4-hour delivery period.** They can choose which delivery period to target.
- The service is required during **all weekdays in a month.** Requirements remain the same across each weekday the service is required to be delivered.

DELIVERY PERIOD OPTIONS

Flexibility provider options Weekdays only	Daytime 8am-Noon	Evening 4-8 pm
Winter (Sep-Feb)	Delivery period 1	Delivery period 2
Summer (Mar-Aug)	Delivery period 3	Delivery period 4

1 Everoze, Our top five learnings from the pioneering sustain-h domestic flex trial for homes, December 2021.

CUSTOMER REWARDS & INVOLVEMENT

The Flexibility Provider defines a Target Demand that is suitable for their portfolio, contracting for a Target Demand of X kW, delivered by a portfolio of Y households.

Remuneration is based on the reduction against a pre-established Baseline Demand. Demand is measured and assessed on an aggregate **portfolio** basis.

The Flexibility Provider manages the delivery risk of meeting the Target Demand that it defines.

Baselining is used to measure portfolio performance and calculate payments, where Contracted Capacity = Baseline Demand – Target Demand.

Benefits, Costs/Challenges and Scalability

BENEFITS

Technology

- Sustain-H provides **certainty** that a subset of homes and assets will have lower demand than that considered for network planning.
- The reduced, "adjusted" predicted demand, known months ahead of time, **means DSOs need to budget for less back up reinforcement than they otherwise would have.**
- The drop-to design is technology agnostic and is inclusive of non-dispatchable solutions like energy efficiency. **This removes much of the complexity and consequent cost of service provision that is a feature of 'drop-by' services.**
- Fixing volumes and periods in advance allows flexibility providers to plan for delivery well in advance.

Customer acquisition

- A scheduled service is capable of attracting a **wider pool of service providers[2].** Sustain-H sits alongside dispatch-driven flexible power services and is designed for homes and assets that won't have the ability or desire to give up control.

COSTS/CHALLENGES

Customer acquisition

- Participant feedback showed that **remuneration** based on the value of an average Constraint Management Zone is insufficient. This is due to high locational variability in value of constraint management, with a few high value zones and large number of medium to low value zones[1].
- **Neutral market facilitation** limits the scope of the DSO . This relies on an intermediary for contracting with providers who must interpret the service procurement, typically framed around the DSO technical requirements and timescales, into a viable customer proposition. Done well, there is scope for the stacking or revenue streams whilst simplifying the customer journey. However this creates and additional dependency in the process. Without this intermediary the service is not suitable for people's homes, where provision of DSO services is overly complex and is not a primary concern.

SCALABILITY

- National Grid aims to resolve only the high priority learnings emerging from the Sustain-H trial before launch.
  → The new procurement platform will be for **all flexible power services** (Sustain-H, Intraflex and Secure, Dynamic, Restore).
- For the initial commercial roll out, Sustain-H will target higher impact demand technologies by focusing on specific technologies.
- Procurement, validation, data delivery, assessment and payment should be digitalised and automated **to reduce manual intervention to a bare minimum** and keep costs down.
- Sustain-H will focus on standardisation of procurement and contracting across services, in order to enable a clear pathway to commercialisation and revenue stacking.
- Domestic energy efficiency solutions require a **deep understanding of people and their homes,** suggesting that a successful approach will be local and customer-focused, not centralised and technocratic.

2 Everoze, Our top five learnings from the pioneering sustain-h domestic flex trial for homes, December 2021.

TasNetworks / Reposit

CONSORT

Bruny Island Battery Trial

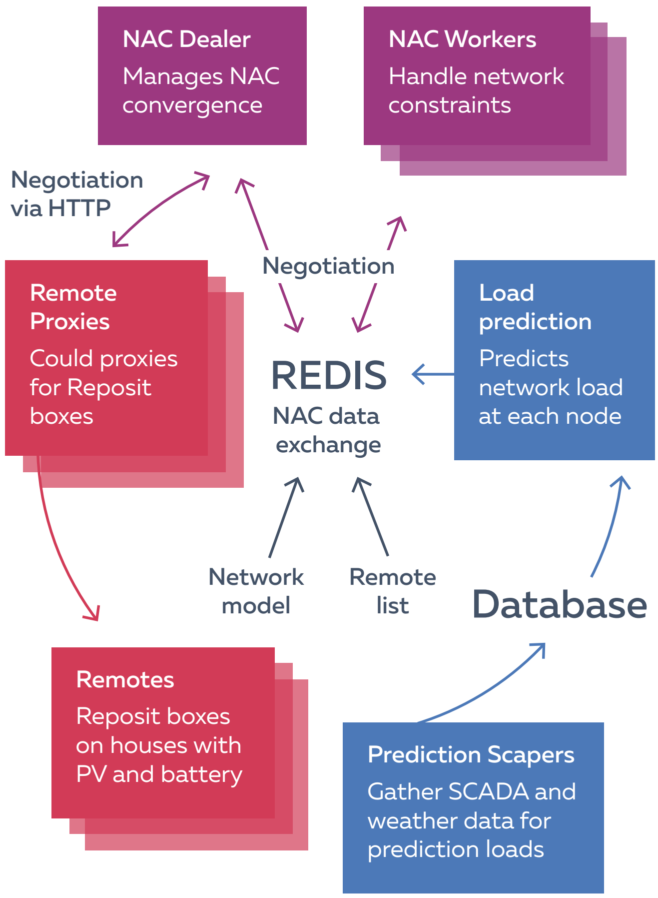
ORGANISATIONS INVOLVED	DSO TasNetworks | Aggregator Reposit Power		
APPROACH TO NETWORK SUPPORT	Direct procurement (bilateral arrangement for fixed dispatch payments)	Dynamic network pricing for energy reserve / energy usage payments	
CONSTRAINTS ADDRESSED	Thermal	Voltage[1]	
CUSTOMERS PARTICIPATING	C&I	Residential	
TYPE OF CER	Solar PV, Battery		
IMPLEMENTATION PHASE	Pilot	Trial	Commercial roll-out

Overview

APPROACH

Network-Aware Coordination (NAC) is the key technical innovation at the heart of the CONSORT project. CONSORT demonstrated how NAC can coordinate CER to manage network constraints at the lowest overall cost to the network and prosumers. The NAC Dealer orchestrates the negotiation between the NAC Workers, which model and solve network power flows, and CER aggregator energy management systems.

Every 5 minutes, the NAC generates a price for the energy supplied by houses. It then decides whether to dispatch diesel from the mobile generator or encourage dispatch from the remotes (batteries managed by Reposit) at a cost given by the latest negotiated NAC prices.



1 Only preliminary trials of voltage control ("proof of concept") were tested here.

SERVICES AND SCENARIOS TESTED IN THE TRIAL

DISPATCH METHOD		PAYMENT TYPE[2]		
FIXED	FIXED	FIXED	ENERGY RESERVE	ENERGY USAGE
Dispatch based on simple timer, e.g., between 4pm and 6pm. Dispatch manually scheduled ahead of event. No load forecasting/ automation.	Battery dispatch using Network Aware Coordination algorithm. Automated dispatch. Load forecasting algorithm.	Customers paid $1/kWh for energy discharged into the grid. Customers notified post-event of amount of payment.	Customers paid variable amount related to their utility in resolving the network problem. Customers notified before the event of amount of payment.	Customers paid variable amount related to their utility in resolving the network problem. Customers notified after the event of amount ofpayment.

Benefits, Costs/Challenges and Scalability

BENEFITS[3]

Technology

- NAC made the **dispatch more efficient** and doubled the effectiveness of battery storage.
- NAC as constraint agent has shown great potential as a mechanism to **ensure the network always remains within its operating limits.**

COSTS/CHALLENGES

Technology

- The optimal power flows accounted in the reward structures were **too locationally granular and challenging to scale.**
  → Calculating the Shapley value of a network support event proved to be exceptionally difficult and made it infeasible to use as a method of generating spot or even close to real time prices.
  → NAC being both the customer agent and the DSO agent working to find the optimal price required too many nodes (one price per connexion) and the iterative overheads (price recalculated every 5 minutes) made the approach unfeasible.
- The approach was **unfeasible for addressing more than one network constraint.**
- **The number of batteries/CER assets available were insufficient** to adequately address the constraint.
- Being in a rural area, the installation was difficult due to rural properties usually having a private pole and the frequent Wi-Fi connectivity issues.
- The algorithm required accurate short-term (<24 hours ahead) predictions of load to function correctly. This was challenging given that data collection was manual, and quality of data was low.

Customer acquisition

- The customer target did not have the economic resources to purchase batteries and had to be provided with a subsidy to afford the batteries.

SCALABILITY

- The approach taken by CONSORT was rendered **unscalable** to a larger number of participants due to the computational intensity of the algorithm and its inability to address more than one network constraint.
- Having the **sociology team** is valuable in understanding the commercial viability of a project.
  → For customers to become a key providers of network services they should be engaged early and often. It is important to provide real-time relevant feedback.
  → Customers and installers are often ill-informed about the benefits of grid participation which can limit uptake of these technologies. It would be beneficial for a trusted party to step into an "informing" role to assist uptake.

2 Implementing the reward structures algorithm proved problematic because the algorithm was very computationally intensive and attempts to simplify it were difficult. Only one trial was attempted using the full Shapley value calculation.
3 Consort, Trial Deployment,

Energy Queensland – Energex and Ergon Energy

PeakSmart

ORGANISATIONS INVOLVED	DSO Energy Queensland (Energex, Ergon Energy Network) | Individual customers		
APPROACH TO NETWORK SUPPORT	**Direct procurement (demand response)**	Dynamic tariffs	
CONSTRAINTS ADDRESSED	**Thermal**	Voltage	
CUSTOMERS PARTICIPATING	C&I	**Residential**	
TYPE OF CER	Air conditioning		
IMPLEMENTATION PHASE	Pilot	Trial	**Commercial roll-out**

Overview

APPROACH

PeakSmart uses innovative technology developed by air conditioning manufacturers to deliver energy efficiencies in periods of high demand. The DSO provides a signal receiver that is connected to the air conditioner unit by the installer.

During days of peak demand, the DSO **sends a signal via the powerlines** (using existing ripple control infrastructure) which talks to the unit for short periods of time and engages its in-built energy efficiencies to cap the units energy use (like in an 'economy' mode).

The technology is only activated when the electricity network reaches peak demand, only for a few hours on certain peak days (either very hot or very cold), called a PeakSmart event.

There are 3 Demand Response Modes for air conditioners, depending on how extreme the need for demand management becomes:

- DRM1: Compressor off
- DRM2: capped to operate at 50%
- DRM3: capped to operate at 75%

CUSTOMER REWARDS & INVOLVEMENT

PeakSmart uses fixed one-off rewards which vary depending on the cooling capacity of the PeakSmart air-conditioner. The customers are rewarded in exchange for control of their appliance during PeakSmart events. Rewards are also distributed to builders and developers who include air-conditioners in new builds.

REWARD	$200	$400
COOLING CAPACITY	Greater than 4kW or less than 10kW	10kW or more

Benefits, Costs/Challenges and Scalability

BENEFITS

Customer acquisition

- **Working directly with industry partners** who could talk to the customers and explain how it would impact them was helpful in acquiring participants.
- **Opening the cashback reward to developers and builders** removed a lot of the barriers in customer acquisition and ramped up the number of installations.

Technology

- **The number of technical interventions** required in peak demand periods has been reduced.
- Using a 4-hour notice period means that PeakSmart has the ability to respond in case of emergency events that cannot be forecasted months in advance.

COSTS/CHALLENGES

Technology

- PeakSmart addresses whole of network constraints and is purely designed to manage peak demand.
- Operationally, PeakSmart could adopt a more granular approach (e.g., to the Zone Substation level) but the **overheads to develop** upfront schedules of events incurred would be too high.
- PeakSmart has **no visibility on the status of the CERs** (i.e., active, decommissioned) as well as how much flexibility is procured by each, which deters its ability to locate where most flexibility is used.

SCALABILITY

- There are **over 140,000 PeakSmart enabled air-conditioners** connected to their electricity network, and participation is increasing every day.
- They plan to onboard more customers. Maintaining parity and managing costs efficiencies where they can is the priority.
- Potentially, moving away from providing rewards for connections of individual appliances and looking at **whole of home.**

Western Power / Synergy / AEMO

Project Symphony

Network Support Services

ORGANISATIONS INVOLVED	DSO Western Power | DMO AEMO | Aggregator Synergy		
APPROACH TO NETWORK SUPPORT	**Direct procurement (bilateral arrangement)**	Dynamic network pricing	
CONSTRAINTS ADDRESSED	**Thermal**	Voltage	
CUSTOMERS PARTICIPATING	C&I	**Residential**	
TYPE OF CER	Rooftop solar, battery, controllable load (air conditioning)		
IMPLEMENTATION PHASE	**Pilot**	Trial	Commercial roll-out

Overview

APPROACH

Project Symphony is creating three, interconnected platforms to handle different functions of CER participation:

1. **DSO Platform (Western Power)**
Responsible for identifying maximum renewable energy hosting capacity, using advanced metering infrastructure data to create DOEs that equitably allocate network capacity to consumers.
2. **Distribution Market Operator (DMO) Platform (AEMO)**
Responsible for receiving bids from aggregated CER via the aggregator and dispatching them in wholesale electricity markets or as a NSS (as requested by the DSO).
3. **Aggregator Platform (Synergy).**
Responsible for onboarding residential CER, managing and dispatching flexibility, and post-event analysis

Project Symphony is testing **network support services (NSS)** by the DSO forecasting capacity shortfalls or degraded power quality that could be resolved through NSS. Western Power then enters bilateral contracts with aggregators for the identified service. When that service is required, the DSO instructs its NSS requirements to AEMO (via the DMO Platform), who sends that request as part of the market dispatch process to the aggregator platform.

CUSTOMER REWARDS & INVOLVEMENT

- A baseline is calculated based on a different method for each CER type (e.g., battery, air conditioner, hot water load). However, being an "off market" pilot, Project Symphony has not yet included the testing of those features[1].
- For the pilot, a $100 credit is provided to each customer in return for participating.

1 ARENA, Project Symphony DER Service Valuation Report, 2022

SERVICES AND SCENARIOS TESTED

ENERGY SERVICES BI-DIRECTIONAL	NETWORK SUPPORT SERVICES (Focus)
Participation in the balancing market which determines economic (most economically efficient) dispatch of generation to meet system demand as managed by AEMO.	A contracted service provided to help manage network constraints – help manage distribution level peak demand and/or voltage issues as identified by the Distribution System Operator (DSO).
CONSTRAIN TO ZERO	**ESSENTIAL SYSTEM SERVICES (ESS) CONTINGENCY RAISE**
Instructions are sent from the AEMO platform to the aggregator platform, to constrain energy output from CER to zero export (net) or zero output (gross). At scale, this could be offered as a market or retailer service.	CER response to help restore a local deviation in frequency to normal levels (due to loss of a large generator or load).

Benefits, Costs/Challenges and Scalability

BENEFITS

Technology

- **Successful minimum viable product (MVP) testing** which simulated the aggregation of energy from 10 customers and 20 assets which was then dispatched and traded over six 5-min trading intervals.

Customer acquisition

- A mix of broad reach (e.g., shopping centre 'pop up' stand) and direct marketing channels provides multiples opportunities to engage customers on the benefits ofparticipation.

COSTS/CHALLENGES

Technology

- The integration was **largely manual** and tested on a considerably **small number of customers.**
- **Ongoing discovery of technical requirements** beyond the planning and scoping phase of the project.
- Limited compatibility / interoperability of CER asset types with, and between, the technology platforms.
- No single technology vendor / provider could provide a turn-key solution.
- Lack of understanding, and adoption, of relevant standards by manufacturers and technology providers.

Customer acquisition

- Customer participation in a VPP, particularly for battery customers, **still requires a significant financial investment**[2]**.** Currently it is hard to justify the benefits of VPP participation when existing tariffs are not more cost reflective and are protecting customers against negative or peak pricing.
- **Lack of customer awareness and understanding** of VPPs and CER orchestration remains a barrier to participation.

SCALABILITY

- An internal **culture change** is required at the Network Operator level whereby NSS are part of the network planning process and are accepted as being as firm as traditional forms of reinforcement.
- Scaling up will require that **the architecture is in place** in terms of technology, capability, people and commercial viability.
- The deployment of the project at commercial scale will depend on the DNSP's capacity and flexibility to pivot in response to external environment changes such as **policy changes.**

2 ARENA, Project Symphony DER Service Valuation Report, 2022

AEMO / AusNet / Mondo

EDGE

ORGANISATIONS INVOLVED	DMO AEMO / DSO AusNet / Aggregator Mondo		
APPROACH TO NETWORK SUPPORT	Direct procurement	Dynamic tariffs	
CONSTRAINTS ADDRESSED	Thermal	Voltage	
CUSTOMERS PARTICIPATING	C&I	Residential	
TYPE OF CER	VPP		
IMPLEMENTATION PHASE	Pilot	Trial	Commercial roll-out

Overview

APPROACH

- EDGE is testing bilateral contracts for network services triggered by the DSO via a common industry data exchange hub, for both thermal and voltage management. In EDGE, customers / their agents use wholesale and local network price signals to decide which services they provide using CER, this is not co-optimised centrally by AEMO.
- 3 different firmness levels are used: **low, medium** and **high,** for which timing, pricing and location differ.
- Demand reduction services are the primary testing focus.

CUSTOMER REWARDS & INVOLVEMENT

- Low Customer Effort - involvement is in line with customer agreement when signing with an aggregator.
- Depending on their agreements, aggregators may pass on some or all of the value of the contracted service to customers.
- For **negotiated prices,** the prices are computed based on the:

1. Risk value (risk to the network)
2. Willingness to pay for a particular service

- EDGE is an off-market trial – rewards are not paid to customers / their agent. Aggregators are instead remunerated for participation in the trial and recruitment of customers.

SERVICES AND SCENARIOS TESTED IN THE LOCAL SERVICE EXCHANGE (LSE) PLATFORM

Tested in trial

	DEMAND INCREASE/REDUCTION			VOLTAGE MANAGEMENT		
	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH
	LOW		MEDIUM		HIGH	
Example use case	Spontaneous operational use-case trigger, event related. e.g., community event		Linked to operational planning use-case, weather-related. e.g., peak demand reduction service required due to heatwave		Network planning capex deferral use-cases and network augmentation expenditure. e.g., feeder with high overloading probability/incidence – peak demand reduction service required	
Pricing	Short-term contract, no guaranteed availability. Negotiated pricing, competitive bidding.		Seasonal contract with negotiated availability and pricing.		Longer-term contract with guaranteed availability and agreed pricing.	
Timing	1-2 days in advance, dispatched with 1.5 hours notice.		Seasonal		1-year ahead	

Benefits, Costs/Challenges and Scalability

BENEFITS[1,2]

Technology

- Increased flexibility in the management of network constraints and deferral of capital expenditure.
- Increased visibility and market access of cost competitive CER capacity released by management of distribution network constraints could ultimately drive down the wholesale price of electricity of distribution network constraints.
- Economies of scale and scope realised from the use of standardised transactions and the data exchange hub model.
- Financial potential to use some resources for both the wholesale market and local services, hence getting paid twice for a given amount of export by earning the wholesale price and the reward for network support.

Customer acquisition

- Non-financial benefits such as, supporting sustainability, renewables and energy resilience are all important drivers of customer participation. Often, a customer's priority is to maximise self-consumption of solar generation and that is what they expect aggregators to prioritise.
- Customers can easily (with minimal cognitive burden) be remunerated via their aggregator for their flexibility from both Wholesale and Network Services market transactions.

COSTS/CHALLENGES[1,2]

Technology

- Uncertain costs. Costs could be limited assuming Exchange Hubs already exist for other reasons, but could be quite high otherwise.
- Baselining for measuring aggregated CER services is still uncertain.

Customer acquisition

- The cost of battery and solar generation equipment is a significant hurdle for prospective customers.
- In the high firmness case, the aggregator needs to ensure that they will deliver the contractual arrangement. This may require additional capability building and mitigate the aggregator's willingness to comply.
- Customer perception and understanding of aggregated CER varies extensively and is often limited. It is crucial to ensure that customers are able to fully comprehend the potential benefits of trading flexibility for both Wholesale and Network Services, in order to successfully attract and retain them. This is true to a certain extent for all VPPs, but likely more so for more advanced approaches.

SCALABILITY[1,2]

- The trial is currently testing the design of the LSE and provides for procuring network support services through this. The next stages of the trial could help inform on the market acceptance and commercial viability of the project.
- Despite the uncertainty of costs associated with establishing the LSE, the economies of scale realised could be significant once the market is underway.
- There is a need for DNSPs to develop the required skillset to facilitate DSO functions and gain a deeper understanding of customer expectations.

1 AEMO, Project EDGE CBA - Draft Methodology for Consultation, July 2022
2 Interview with Project EDGE team (AEMO, AusNet, Mondo)

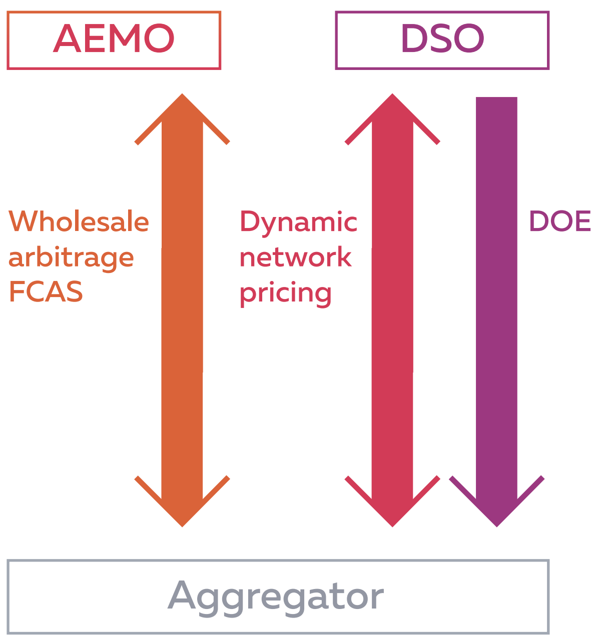
Ausgrid / Reposit Power

Project Edith

ORGANISATIONS INVOLVED	CMO[1] AEMO / DSO Ausgrid / Aggregator Reposit Power		
APPROACH TO NETWORK SUPPORT	Direct procurement	**Dynamic tariffs**	
CONSTRAINTS ADDRESSED	**Thermal**	**Voltage**	
CUSTOMERS PARTICIPATING	C&I	**Residential**	
TYPE OF CER	VPP (battery)		
IMPLEMENTATION PHASE	Pilot	**Trial**	Commercial roll-out

Overview

APPROACH



- The DSO (Ausgrid) sends the aggregator (Reposit) DOEs and dynamic network pricing for each site, and the aggregator then bids capacity into energy markets that is within the limits of the DOEs.
- By using **time and location-specific incentives,** two-way dynamic prices seek to make unused network capacity available to CER as well as reward behaviours that support the local network.
- Dynamic prices are **calculated and refreshed at a set interval,** such as once a day. Dynamic pricing components for both imports (load) and exports (generation) are published for each defined sub-section of a distribution network.

1 Central Market Operator

TWO MAIN TOOLS FOR MANAGING POWER FLOWS ON THE DISTRIBUTION NETWORK:

Dynamic Operating Envelope (DOE)

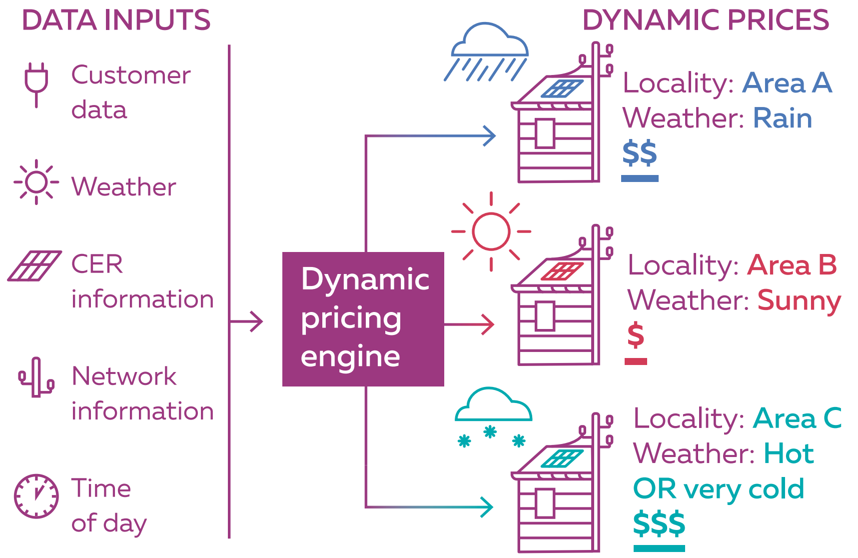
DOEs **change the upper and lower limits** on customers' load and generation.

These flexible limits can **vary over time and location,** depending on available capacity in each area of the network.

The limits can be refreshed and published **at five-minute intervals,** with day-ahead forecasts, to match energy market settlement periods.

Used to define the absolute limit at each location.

Dynamic Network Pricing



Incentivises actions that are beneficial for reducing network costs within the DOE limits.

Benefits, Costs/Challenges and Scalability

BENEFITS

Technology

- **Minimal upfront investment,** leading to reduced costs to customers while unlocking more value from CER.
- Responses to dynamic pricing can **help identify sections of the network where capacity is highly valued** to help better manage and plan for the network.

Markets

- DOEs **provide certainty**
  - → to market operators about wholesale and FCAS reliability, and
  - → to VPPs about available capacity for system services (better identification of network constraints).
- For VPPs, dynamic pricing enables
  - → **Optimised bids** on markets.
  - → Unlocking benefits from **negative network prices.**
- Dynamic pricing enables DNSPs to **optimise the use of the market** and efficiently **allocate network capacity** while rewarding network support.
- Dynamic network pricing provides aggregators access to information about network costs and enables a share in network benefits.

COSTS/CHALLENGES

Technology

- Operational burden and extra data exchange caused by the point to point design approach.

SCALABILITY

Markets

- Market integration and network support services are facilitated because Edith extends the current network tariff structure. Therefore, no new markets need to be developed.

Technology

- The concepts being tested could be applied to **other CER,** such as, electric vehicles and 'smart' household appliances (e.g., hot water systems, pool pumps).
- **Regulatory changes** to network pricing may be needed in the future, to implement dynamic pricing at scale and ensure that customers are priced fairly.
- Builds on existing capabilities.

Customer acquisition

- **Lack of CER ownership** is a challenge that needs to be overcome in order to scale up.

Ausgrid | reposit