KSR 12 Converge Project final knowledge sharing report

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CONVERGE

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Executive Summary

The Converge trial was a 2 ½ year trial that involved implementation and testing of a new concept called Shaped Operating Envelopes (SOEs). It included two streams:

- A technical demonstration of SOEs, and
- Social science research to understand consumer and stakeholder expectations and views on SOEs.

The primary innovation in SOEs was to involve aggregators specifically in the process of allocating network capacity among owners of Distributed Energy Resources (DER). This enabled two values:

- Capacity allocation that was more reflective of peoples' intent to use the electricity network, and
- Automatic procurement of network support services where it is economically favourable.

We demonstrated SOEs in practice with 1,001 existing ACT battery owners. We showed that there are two conditions which are required for SOEs to effectively manage grid congestion and create better financial outcomes than DOEs:

- SOEs must include PV, batteries, and other types of DER, and
- Either participants must be participating fully in the wholesale energy market, or we need to reassess how self-consumption is foregrounded within SOEs.

Participants in the Converge trial saw only very small changes in their battery behaviour during their participation. Most saw less than 10 kWh of battery behaviour change over the length of the trial. This meant many participants we spoke to were relaxed about their participation.

Participants were long-term battery owners who already had an established relationship with an aggregator whom they were relatively comfortable with. If the Converge participation experience holds outside the trial, the addition of SOEs to an existing virtual power plant (VPP) relationship may be the best approach to scaling SOEs. This leads us to our view of where SOEs are likely to fit in the energy system of the future, shown in Figure 1. In this future, SOEs are part of VPPs. Therefore, it is likely participants will decide if they want to participate in SOEs as they are considering whether to participate in a VPP. This emphasises the role of aggregators as important intermediaries in the uptake and scaling of SOEs. It is likely that SOEs will coexist with DOEs in the future.

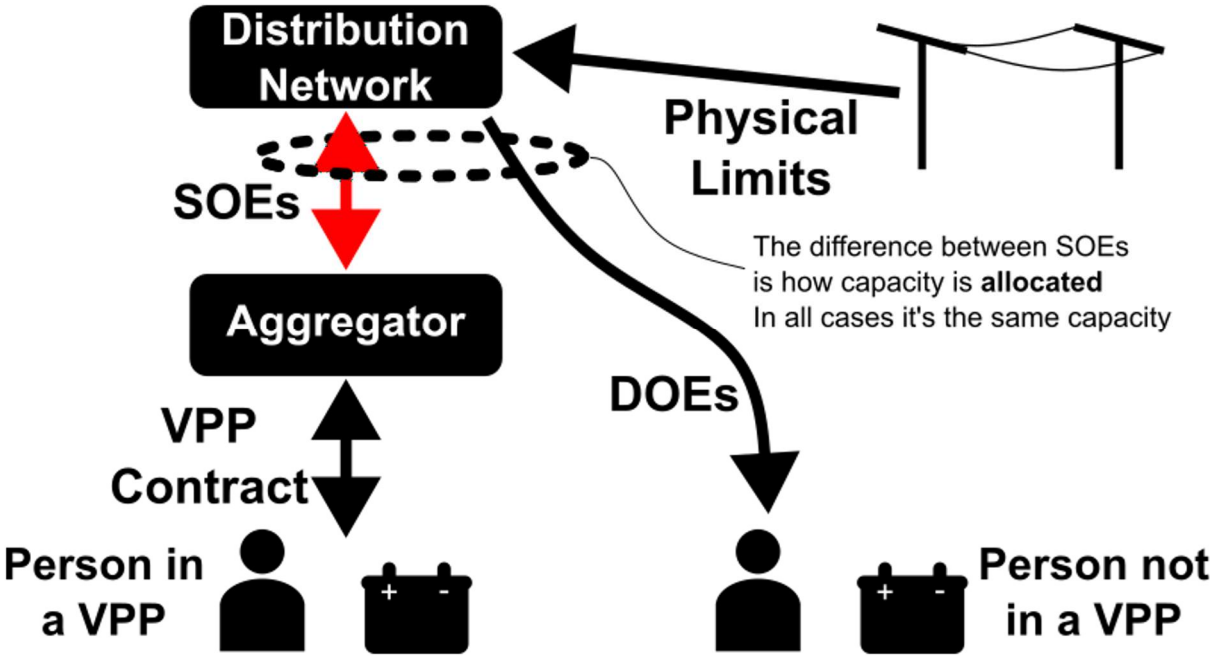


Figure 1 the role of SOEs in the future energy system

There were several major themes emergent from our research:

The role of values

SOEs were built to enable self-consumption of locally generated PV by participants. Indeed, most participants were self-consuming their excess PV often, and told us that self-consumption was a major reason for them to purchase a battery in the first place. This was echoed by stakeholder participants in our research who felt that self-consumption was important for the energy system to enable and support. However, this reduced the ability of the algorithm to uptake offers to support the network made by aggregators on behalf of participants by nearly 90% - a very significant impact. Other values were also raised by householders such as equity, environmental stewardship, and affordability. Householders emphasised to us the importance of these values. Their expectation is that if a benefit of SOEs was an increase in consideration of householder values, these values should be considered in the fundamental design of the algorithm. **Our reflection is that householders are likely to conceptualise having their "preferences incorporated into SOEs" much more broadly than industry does, thus providing fertile ground for misunderstanding, disappointment and distrust if not carefully and pre-emptively addressed.**

Reducing complexity and the parts of SOEs

The Converge trial was complex to deliver. In part this was because there was no existing framework for implementing SOEs. Aggregator agreements to deliver Converge were bespoke and time consuming to negotiate and key assumptions around how aggregators could share bids with the Converge algorithm were not correct. If SOEs are to scale, the underpinning relationship between aggregators and DNSPs needs to be standardised.

However, participants in our social science research were wary of the additional complexity introduced by SOEs. The Converge trial showed that there may be merit in SOEs over DOEs, but did not build a holistic, costed implementation model. This should be considered prior to deciding on whether SOEs are to be scaled. Stakeholder participants noted that many of the parts of SOEs are currently being considered for inclusion in their DOE approaches.

Therefore we recommend that people who are considering using SOEs pay mind to complexity and carefully consider if SOEs are warranted, or whether parts of SOEs can be implemented more simply to achieve some of the benefits through DOEs.

The importance of quality data

Like other DOE and demand response trials, data quality was a challenge. Quality network configuration and real-time state and consumption data is needed for the algorithm to operate effectively. This data is clearly critical for networks to assess their capacity.
Therefore we recommend that networks undertake a concerted effort to improve real-time and standing data quality as part of uptake of SOEs.

Communicating SOEs

A coordinated communications campaign would assist to explain how CER and operating envelopes are being applied and the important role that householders are playing in the energy transition. Clear, consistent and effective communication could help drive the energy transition and give householders agency to better utilise their CER as they see fit. For example, our social research revealed that some people wanted to share their excess energy with others. Others might consider sharing their excess energy if they could be assured that their energy needs are adequately met first. There is an education piece that could occur in that space to assist.

We have six main findings from the Converge trial:

Finding: SOEs are part of the DNSP – aggregator relationship

SOEs may be most beneficial if they are part of aggregator VPP products in the future. This enables aggregators to build them into products for those consumers who desire market participation. Consumers who do not desire market participation through VPPs will likely remain on DOEs.

Industry will need to work together to standardise the underpinning DNSP/aggregator relationships that enable SOEs.

Finding: The role of values in SOE design

Consumer values are important inputs into the design of SOEs. The self-consumption design decision underpinning SOEs is a clear example of this. People ideated many other values to us in our social research and these could be inputs into further design to refine the SOE concept.

Part of values is consideration of how future participants will be able to see they have been met. This will require clear, targeted and transparent communication with consumers. It may also require additional types of information to be communicated between DNSPs and aggregators.

Finding: How SOEs could influence DOEs and other technologies

SOEs are a set of approaches. Taken as separate from SOEs themselves, they potentially can provide useful improvements to other processes.

- Better load forecasting can enable DOEs to be more reflective of consumer energy needs
- Demand response capacity data can improve planning processes and comparison of network and non-network options.

Finding: The role of aggregators, solar installers, and other key intermediaries

Intermediaries will be important in the scaling of SOEs. Aggregators are a key intermediary – particularly given SOEs are likely to be part of VPPs in the future.

Other intermediaries will also be important though such as DNSPs, early adopters, solar installers, family and friends. As the concept of SOEs is further developed, their part in intermediating SOEs should be further defined.

Finding: The importance of data and information and transparency

Technical data is important to SOEs. This includes how the network is configured and its current state. Initiatives to install devices that collect more data should be continued.

Participants in our research also expressed a desire for 'opening up' of the operation of the SOE algorithm so they can see why their devices were being operated as they were.

Finding: the importance of communication

Importance of transparent, clear, and targeted comms to bring the consumer along on the journey. The energy sector is shrouded in mystery – give the customer a peek under the hood.

Contents

Introduction

The Converge trial was a 2 ½ year, $8.4m project that tested a new approach to integrating network capacity considerations into Virtual Power Plants (VPPs). It used a new technology called Shaped Operating Envelopes (SOEs) to explicitly integrate aggregators into the capacity allocation processes. This enabled capacity to be allocated in a way that is reflective of consumer needs, as well as automatically assess the need for and procure network support to resolve grid constraints. The SOE technology is described further in 1.

The Converge trial involved building the SOE algorithm and implementing through integration with two aggregators. As is expected in a trial, several of the initial assumptions underpinning SOEs were challenged and reframed during the trial. These are described in 2. Outcomes of the technical trials in terms of grid benefits is described in more detail in 3.

The Converge trial tested SOEs with 1,001 ACT battery owners. These were long-term battery owners who had installed a system under the ACT NextGen battery subsidy program. This makes Converge unique because participants were already familiar with batteries, so only the concept of SOEs was new to them. We have described the consumer side of SOEs in 4.

The Converge trial has shown that SOEs deliver the most value when DER is actively participating in energy markets. This means that SOEs are likely to be part of VPP participation for future participants. SOEs thus are a type of relationship between DNSPs and aggregators, and a platform on which VPP products can be built – in some ways analogous to how energy retailers build products on network tariffs. We discuss this landscape in 5. This is then derived into concrete next steps in 6.

Acronyms/Glossary

ACT	Australian Capital Territory
AEMO	Australian Energy Market Operator
Aggregator	An agent who aggregates energy production and consumption from multiple sources to present to the grid as a single source
ANU	Australian National University
ARENA	Australian Renewable Energy Agency
CER	Consumer energy resources. Often used interchangeably with DER. We have used DER in this report.
DER	Distributed Energy Resources
DNSP	Distribution Network Service Provider
DOE	Dynamic Operating Envelope
EV	Electric Vehicle
FCAS	Frequency Control Ancillary Services
FOE	Fixed Operating Envelope
FRMP	Financially Responsible Market Participant
Intermediary	Intermediaries are human actors who have a function or purpose in any given system
MASP	Market Ancillary Services Provider
NMI	National Metering Identifier
OLTC	On Load Tap Changer
PV	Photovoltaic
RIT-D	Regulatory Investment Test for Distribution
SNM	Strategic Niche Management
SOE	Shaped Operating Envelope
VPP	Virtual Power Plant

Navigating Converge knowledge sharing reports

Final technical report

This report summarises the technical outcomes of the project, including:

- Results of the live trial with 1,001 ACT battery owners,
- Results of modelling undertaken to compare DOEs and SOEs,
- Outcomes of the proof-of-concept test of the "Real-time RIT" approach.

The project also proposes next steps for the SOE approach from a technical point of view.

Final Social Science report

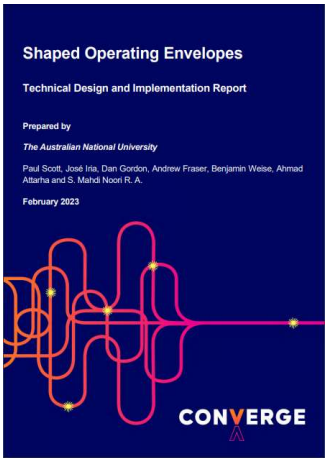
This report brings together the findings of the stakeholder and participant qualitative research. It covers:

- Perspectives on SOEs,
- Perspectives on network capacity management,
- Insights around trust and expectations of energy system stakeholders,
- The role of intermediaries, and
- Connections between SOEs and other practices.

Final knowledge sharing report (This report)

This report summarises and relates the findings of the final technical and social science report together. It proposes a combined coherent vision for how SOEs could be scaled. It covers:

- The "as built" SOE technology,
- A summary of technical and social findings,
- A vision for the future of SOEs, and
- A set of next steps.



Technical design and implementation report

This report describes the concept of SOEs and how they are being implemented in the Converge trial. It covers:

- How SOEs were derived from DOEs,
- Key concepts including bids, contributions, and envelopes,
- Implementation mechanics and architecture,
- Data flows and,
- Examples of the SOE approach.

Intermediary insights on dynamic and shaped operating envelopes

This report describes the outcomes from interviews with 'intermediaries' (or energy system experts) on the concepts of DOEs and SOEs. It covers:

- Perspectives on DOEs and SOEs
- Insights on the current state of application of DOEs
- How knowledge and understanding about SOEs, DOEs, and their underlying technologies are being shared, developed and reframed.

1 The Shaped Operating Envelope technology

For more information

For technical implementation details see *"Shaped operating envelopes: Technical Design and Implementation Report* [1]*".*

For discussion on stakeholder perspectives on the SOE technology see *"Social science report 1: intermediary insights on dynamic and shaped operating envelopes* [2]*".*

For technical results of the trial see *"Trial of Shaped Operating Envelopes Final Technical Knowledge Sharing Report* [3]*"*

For more details on consumer perspectives of SOEs see "*Converge Social Science - final report* [4]*"*

The Converge Trial tested a technology called "Shaped Operating Envelopes" (SOEs) — a novel approach to calculating Dynamic Operating Envelopes (DOEs). DOEs are a class of techniques for allocating constrained distribution network capacity to aggregators and/or end customers. SOEs extend this approach by factoring in aggregator preferences. Inclusion of aggregators is expected to be beneficial because aggregators have better visibility of, and data about, behind-the-meter consumption, and they may be better positioned to anticipate customer preferences (including market participation preferences). More detailed information on DOEs can be found here [5], [6], [7] .

SOEs are driven by an expectation that more consumers are likely to want to participate in Virtual Power Plants (VPPs) in the future. VPPs are aggregations of many consumer devices, such as solar PV and home batteries, that participate in energy markets and sell services to other energy sector stakeholders (e.g. networks, retailers, and generators). They involve an organisation (aggregator) who manages the bidding and grid interaction process on the customer's behalf. Previous projects that have explored widespread participation of DER in energy markets have shown that VPPs can cause congestion in distribution networks due to their coordinated actions [8], [9].

SOEs aim to improve on DOEs by:

- Improving capacity allocation by accounting for:
    - Aggregator (and, by proxy, customer) intentions and preferences,
    - Market performance of DER, and
    - A view on fairness (described further in section 2.7)
- Enabling networks to automatically procure network support where there is an economic benefit [1].

SOEs primarily modify the process of capacity allocation by including aggregators in it. This is shown in Figure 2.

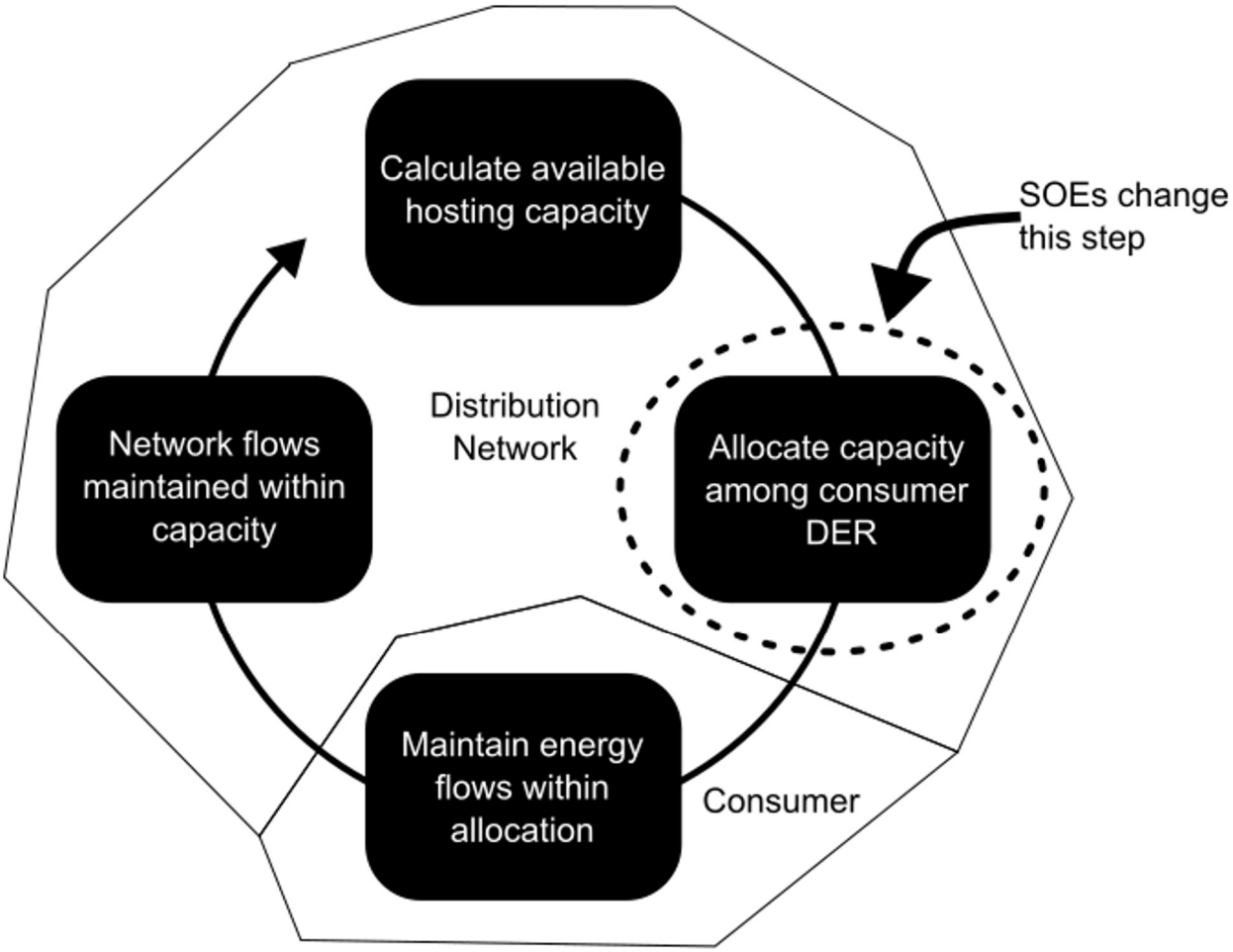


Figure 2 DOE lifecycle and SOE changes (adapted from [5])

SOEs are an evolution of DOEs, which means that many of the concepts from DOEs carry over to SOEs. In particular SOEs carry over the concepts of "envelopes" and "capacity allocation". Aggregator involvement improves the fidelity of this process because it enables the algorithm to more explicitly include information on behind-the-meter assets, and aggregator and customer preferences.

The capacity allocation process includes two steps:

- Aggregators provide their intent to the SOE engine, and
- The SOE engine allocates capacity to those who request it, purchasing flexibility as required and economically favourable.

Aggregator intent is provided through them providing two pieces of information to DNSPs in real time:

- The customer's forecast consumption (or generation) plus error bands, and
- The customer's market and network support bids and capacity.

The SOE engine then allocates capacity, (as well as network support and bids), with the following objectives:

- Maximising the value of bids brought to the market,
- Minimising the cost of network support,

- Ensuring, when possible, that network constraints are not violated,
- Taking into account fairness by providing similarity of envelopes across NMIs of similar type [1].

This process is shown in Figure 3.

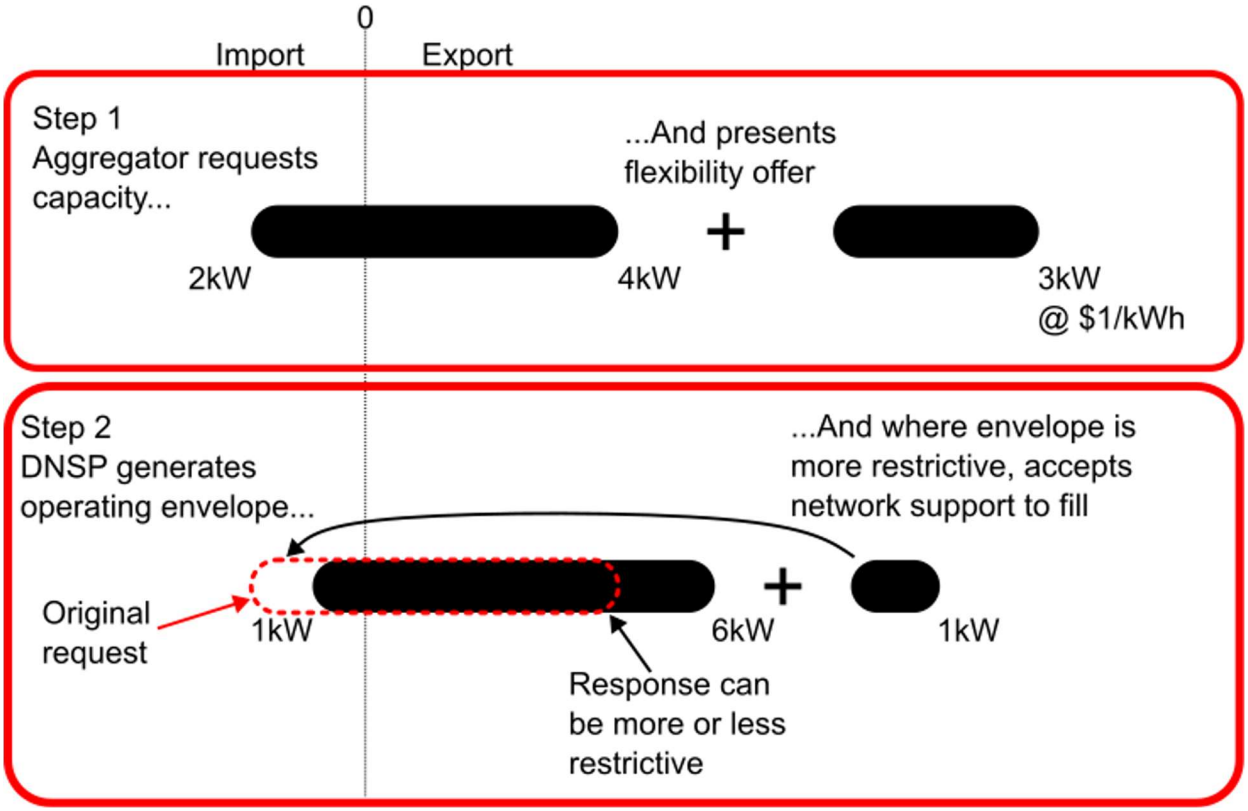


Figure 3 Capacity allocation

SOEs were implemented through elements built by five organisations:

- ANU built the SOE engine itself including relevant data handling, forecasting, and utility servers,
- Evoenergy provided smart meter data and network models,
- Zepben provided network models in a standardised format, and
- The two participating aggregators provided their bids and expected participant consumption and complied with envelopes [1].

2 Implementing SOEs in the Converge trial

Converge was a trial of SOEs based in the Australian Capital Territory (ACT). It involved 1,001 home batteries. As a trial, its main purpose was to "learn by doing". The prototype SOEs tested in Converge differed from what might be expected to be implemented operationally in several ways. Also, there were several learnings and changes that had to be made to SOEs during the trial. These are described in this section.

2.1 How SOEs were applied

In Converge, SOEs were implemented through a network support agreement. This is different to current "flexible export" DOE approaches which are commonly part of PV owner's connection agreements [10] or technical grid connection standards [11].

This impacts how SOEs were applied in the trial:

- Requests to alter consumption or generation patterns in Converge were classed as network support requests and were thus a paid service. This contrasts with other DOE approaches, where requests to alter consumption or generation patterns are an expectation of connection therefore not a paid service,
- Participants were not necessarily in a VPP, and when they were it was only for FCAS and SOEs did not directly impact the bidding process undertaken by the aggregator, and
- Participants were participating in a specific SOE trial, rather than SOEs being a part of participating in a VPP.

There were two participating aggregators in the Converge trial, and each offered participants different value propositions around participating:

- One adopted an "opt-out" approach to participation, with participants paid a share of actual network support revenues, and
- One adopted an "opt-in" approach to participation, with participants paid an upfront payment for participating. They also enforced hard limits on the level of participation for each participant.

During the trial we were not able to get a large enough sample size of participants across both approaches in our qualitative research to fully explore the difference in participant perception across these approaches. Similarly, the technical trial was very short which meant that participants did not see a significant impact on their batteries from SOEs.

However, given the differences in how SOEs were applied in the trial and how DOEs are applied it is likely that neither participation model used in the trial is an accurate reflection of an operational SOE approach. This is particularly true given the extent to which SOEs are linked to VPPs and market participation, which was not tested in the trial. Qualitative research focussed on the acceptability of SOEs themselves, which is described in the Final Social Science Report [4].

2.2 Including zero in SOEs

As described earlier, SOEs are an evolution of DOEs. DOEs can be said to be a “harm minimisation” approach in that they try to avoid network congestion caused by solar PV, batteries, and flexible loads. This resulted in one key design decision for SOEs:

“It should always be possible for people to self-consume”

Technically, this meant that operating envelopes generated by the SOE engine needed to include “zero” or self-consumption, as shown in Figure 4. This acts as an additional constraint to the SOE engine’s ability to procure network support services, as consumption can only be restricted toward zero - envelopes are only able to curtail consumption or generation, not increase it. This design decision had a material impact on the ability of the SOE engine to provide network support, described further under the “grid benefits” section. But also aligned with important participant self-consumption values described further under the “consumer side” section.

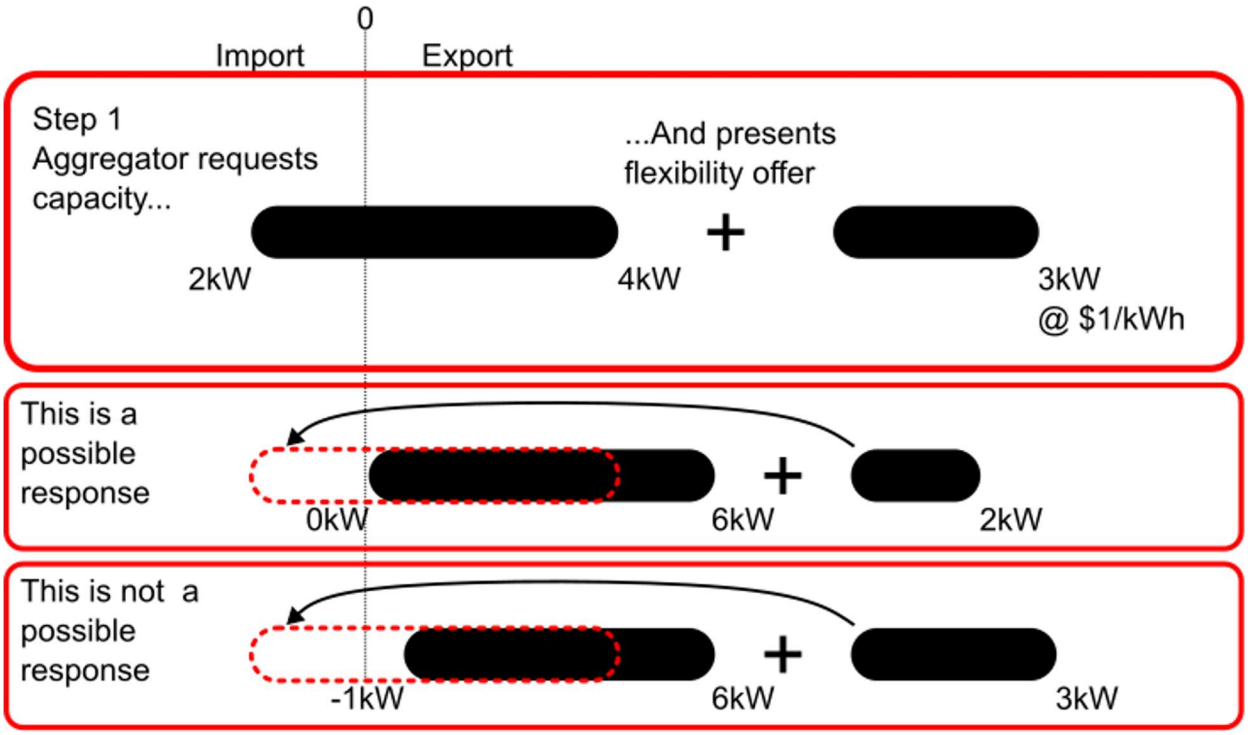


Figure 4 The impact of including the "zero" point in SOEs

2.3 Consumer side application of SOEs

In the Converge trial, all participants had two common properties:

- They all had batteries, and
- It appeared that none were fully dynamically participating in the wholesale energy market.

In the Converge trial, mainly consumer batteries were subject to SOEs. This meant that even though all participants had solar PV, most of this PV was not able to be influenced by SOEs. This interacted with the “includes zero” limit (described above) to limit the algorithm’s ability to manage grid constraints because:

- When participants were generating solar in excess of their consumption and their battery was not full, their battery would typically consume the excess solar generation, bringing the net load close to zero. Extra consumption network support could then not be accepted using the mechanism of envelopes, because this would entail forcing the total power *away* from zero.
- When participants were exporting to the grid it was because their battery was full, so reducing export would have required control of their solar generation.

When it was not sunny the opposite case was often true because participants were using their stored PV energy to supply their own consumption.

Clearly control of PV is technically possible – DOE approaches in South Australia implement it today. The Converge trial used extant control mechanisms which mostly didn't allow control of PV. Today, there is no reason to control PV generation for most consumers as reducing generation can only reduce the value they receive from their PV systems.

2.4 Expectations of bidding vs actual bidding

One of the main purposes of SOEs was to enable networks to "shape" aggregator market bids. The intent was that if networks get advanced view of market bids they can:

- Prioritise the bids that will provide the most efficient market outcomes,
- Ensure that bids will not cause grid congestion, and
- Procure grid support services where this results in a net efficiency improvement.

One fundamental assumption underpinning this was that aggregators developed their market bids through aggregating individual DER.

Aggregators were participating in FCAS markets as a Market Ancillary Services Provider (MASP). Neither were energy retailers (or Financially Responsible Market Participants (FRMPs)). Through engagement with them in the trial, we found that they did not generally derive their bids through understanding the capabilities of each device individually and presenting an aggregate bid to the market. This meant that they did not have the ability to state how each device was to bid into the SOE engine.

The outcome for Converge was that the bids and prices offered to the SOE engine were purely network support offers without a focus on market outcomes and/or the best financial outcomes. The Converge trial therefore evolved to become more focussed on:

- The value of including aggregators in the capacity allocation process, and
- The value of network support in helping the SOE engine manage network constraints.

2.5 Technical capacity, consumer values, and aggregators

The original justification for including aggregators in the capacity allocation process was twofold:

- They had a better *technical* view of their customers' behaviour and flexibility capability, and

- They had an understanding of their customers' *values* and could frame these in terms that had meaning to the SOE engine (e.g. flexibility bids and capacity requests).

There were two pieces of information that are used by the SOE engine to communicate between aggregators and networks:

- Range of expected consumption and generation, and
- Network support offers.

In the Converge trial aggregators were not part of the consortium, so we didn't have visibility on how customer values were considered in their internal algorithms. However, it could be expected that some values are more easily translatable to the technical parameters used in capacity allocation. For example:

- Load forecasting enables aggregators to predict how much capacity their customers need to consume or generate as they usually do, and
- Offering flexibility services meets their customer drivers to maximise the financial value of their devices.

It appeared that aggregator bids for flexibility received by the SOE engine represented the technical capability of their batteries to respond to network support requests, although it is not possible to know if this is truly the case. There is a broader consideration around whether (some or all) consumer values are able to be translated into flexibility bids in the way proposed by Converge, or whether it is appropriate to expect aggregators to be the sole representer of customer values.

There was an intent to consider equity in the capacity allocation algorithm built for Converge, however this was abandoned early in the testing process due to poor outcomes. Equity was the most commonly raised value in the social science research. The "includes zero" limitation does however give a real view of how consumer values (in this case self-sufficiency) can be integrated into technical algorithm design, albeit at the cost of access to significant network support value.

2.6 Reservation ranges vs reservation values

The concept of SOEs was that aggregators provided the SOE engine an estimate of the customer's uncontrolled consumption/generation and a confidence interval. The intent of the interval was to account for uncertainty in the forecast. In the actual trial, aggregators did not supply the confidence interval (e.g. their forecast was a point rather than a range as shown in Figure 3 and Figure 4). This was potentially because aggregator's load forecasts were not designed to produce confidence intervals.

2.7 Inclusion of equity in SOE engine

The SOE engine was originally designed to take a view of fairness into consideration. In the SOE algorithm, this can be thought of as answers to the question "under what conditions would participants be given different envelopes?":

- When there is any reason not to, or
- Unless there is a very compelling reason not to.

During the trial the former was used, so there were a variety of technical and economic reasons that participants received different envelopes. Testing showed the latter resulted in participants being issued envelopes that were more constraining than necessary.

The view of equity used in the technical design is one of many ways equity could be considered. Through our social science research we have built a higher fidelity view on equity from the point of view of future participants in SOE approaches, detailed further in the social science report [4], 4 of this report and 5 of this report.

2.8 Other learnings

This section details other learnings from implementing SOEs in Converge.

Aggregators

There were two aggregators participating in Converge. There was a relatively long process to sign these aggregators on to the trial. The two aggregators also used different approaches to enlist participants in the trial and provide incentives, as shown in Table 1.

Table 1 Aggregator participant offers

	Aggregator 1	**Aggregator 2**
Enrolling in the trial	Opt-Out	Opt-In
Paying incentives	A variable amount paid for each network support event	Upfront payment of $200 for participating in the trial
Level of participation	No specific limit	Maximum level of participation for each participant

Data

Similar to many other trials, obtaining adequate data quantity and quality was challenging. This related to:

- Standing data on assets and configuration (e.g. network data)
- Real-time data (e.g. metering)

3 The grid value of SOEs

SOEs are a new capacity management approach that aims to take aggregators into account directly. However, the actual SOE engine does more than just this. In this section we consider the grid value of SOEs both as a whole and the individual parts.

The Converge project found that SOEs have merit, but unlocking the value of SOEs requires high penetrations of DER that is bidding into the wholesale energy market. Our social research found overall both stakeholders and householders thought that the reasons for SOEs were sound. However, there were indicators that, for several reasons, people may elect not to participate in an aggregation service and/or VPP that SOEs are embedded into. Some of these reasons are that the SOE creates tension with their goals to self-consume energy, to be resourceful, and likely also independent. Understanding how aims for to self consumption of energy or engaging batteries in a market can coexist needs further exploration to understand how it could be negotiated in the future. However, given SOEs are an evolution of DOEs, there is no path dependence and the choice to move from DOEs to SOEs can occur later if DER that dynamically responds to market prices become more prevalent.

There are likely to be regulatory changes needed to enable SOEs, particularly to formalise the relationship between DNSPs and aggregators. In the Converge trial, onboarding aggregators was time consuming and resulted in bespoke arrangements that would increase the complexity of applying SOEs outside the trial.

At a more granular level to SOEs, automated procurement of demand response is a promising way of increasing the amount of demand response that is used for grid management purposes. Our Real-time RIT-D demonstration showed that the capability of automatically collecting demand response potential can also unlock greater use of non-network options in distribution networks.

3.1 What value do SOEs create for the grid?

For more information

See *"Shaped operating envelopes: Technical Design and Implementation Report* [1]*"* section 3 for detailed results from the technical trial, and section 4 for modelling results and comparison with DOEs.

Converge tested the SOE concept using live trials and offline simulations, including:

- Trials with real devices (live trials) using participants spread over several selected feeders,
- Trials with real devices, where all 1,001 customers were modelled as if they were located on a single feeder, and
- Simulations of a future with high levels of batteries, VPPs, and SOEs or other forms of operating envelopes.

The Converge project tested SOEs with 1,001 customers in the ACT. However, spread across the ACT, the penetration of SOEs was still very small, with around 1% penetration of SOEs achieved in the real feeders to which Converge customers were connected. This meant that

while the SOE engine was procuring helpful network support, there was no measurable change in actual network performance. This did however show that the SOE engine was "doing the right thing" in its procurement of network support. The results of one of the trials is shown in Figure 5. The main outcome of this trial is that the overall framework of SOEs works "end-to-end".

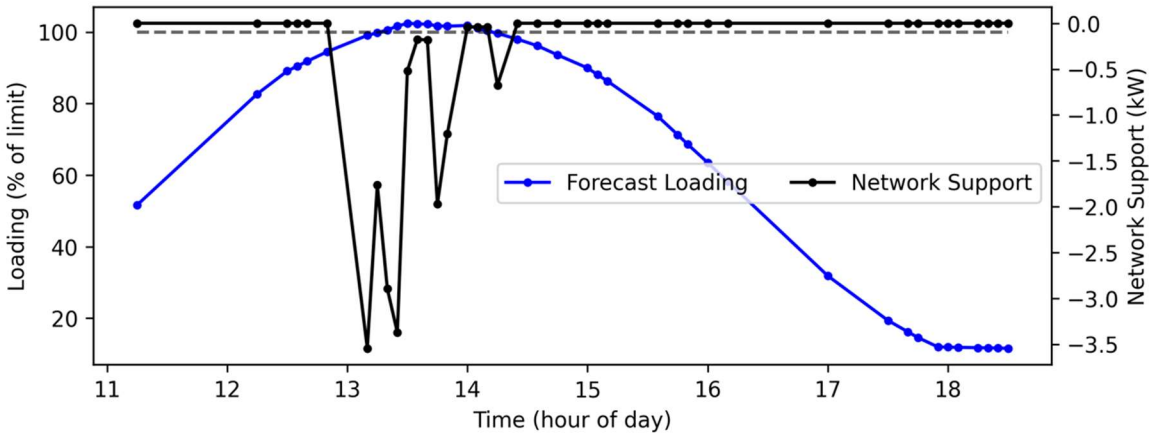


Figure 5. The forecast voltage region and SOE network support. Results of Trial 2 for CITYEA_8LB_EBDEN on 28/11/2023.

The next trial showed what would have happened had all Converge participants been on a single feeder. In this case there would have been around 30% penetration of SOEs on a single network feeder, which is reasonably reflective of overall PV penetration in Australia today. This trial showed a much stronger response and larger grid impact; however, it was still relatively small, with a reduction in voltage violations of around 0.5%. This is shown in Figure 6.

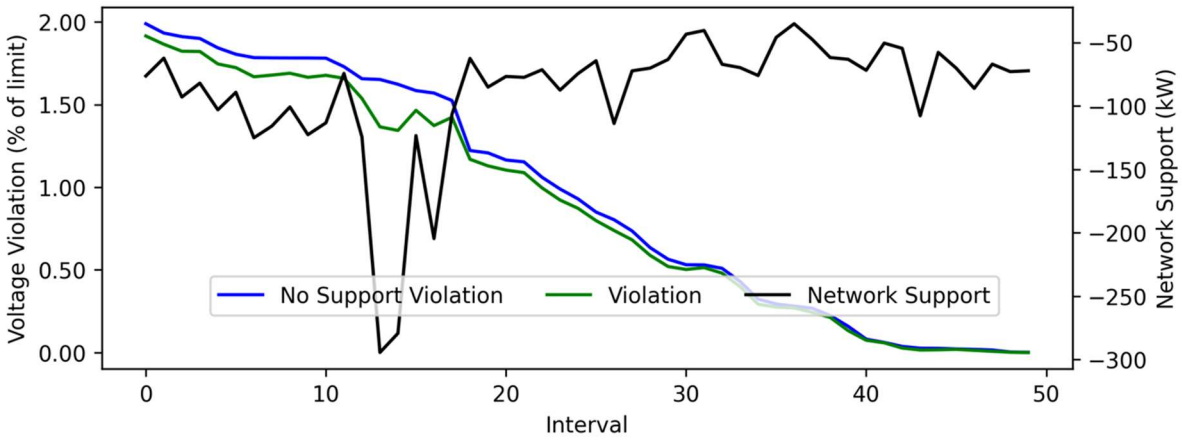


Figure 6. Voltage violation (with and without network support) and SOE network support for the 50 largest voltage violation events. Results of Trial 3 for LATHAM_8TB_LWMLNGLOW on 06/12/2023.

There were two contributing limitations that caused this relatively small response:

- The lack of controllable PV
- The impact of the design decision that envelopes must 'include zero'.

The impact of the second limitation was especially stark. Around 90% of offers could not be accepted because accepting them would mean the SOE engine would need to offer an envelope which didn't include zero.

DOEs are a “harm minimisation” approach. They were defined to maximise the flexibility of DER while avoiding network congestion. An underlying principle was that DER owners should always have the right to self-consume. This design principle was carried over to SOEs. It appears that for SOEs the impact of this principle on the ability of the algorithm to manage constraints in the network is stark. However, the social science research undertaken as part of Converge showed that self-consumption was a strong driver for battery owners, which means the expectation that self-consumption should be acceptable at all times aligns well with customer expectations. Other trials that have not included this design decision (e.g. Symphony [12]) showed that high density demand response can be challenging for consumers. It is thus clear that as SOEs are scaled, the role of demand response vs envelopes will need to be clearly defined and communicated with consumers.

A contributor to the impact of the “includes zero” limitation is that all Converge participants were on standard retail tariffs. These tariffs encourage self-consumption because there is no point at which export would make financial sense. This meant that the Converge participants, who all had PV systems and batteries, often were self-consuming. The simulations had two main differences to the live trials:

- PV is controllable in the simulations, and
- Virtual participants were participating fully in the wholesale energy market.

This trial showed significant benefits to SOEs over DOEs. This is shown in Figure 7.

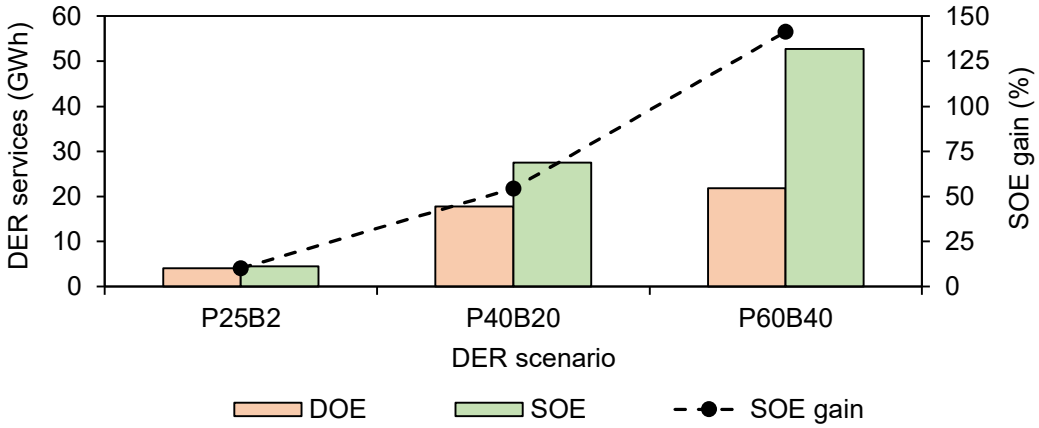


Figure 7. Unlocked DER capacity under SOEs and DOEs.

So, from the results of the Converge trial (both real-life and simulation) there are two conditions which are required for SOEs to effectively manage grid congestion and create better outcomes than DOEs:

- PV must be a controllable asset, and
- Either participants must be participating fully in the wholesale energy market, or the “includes zero” constraint must be relaxed when there is network support.

Given these conditions, SOEs can unlock significant market benefits, as shown in Figure 8.

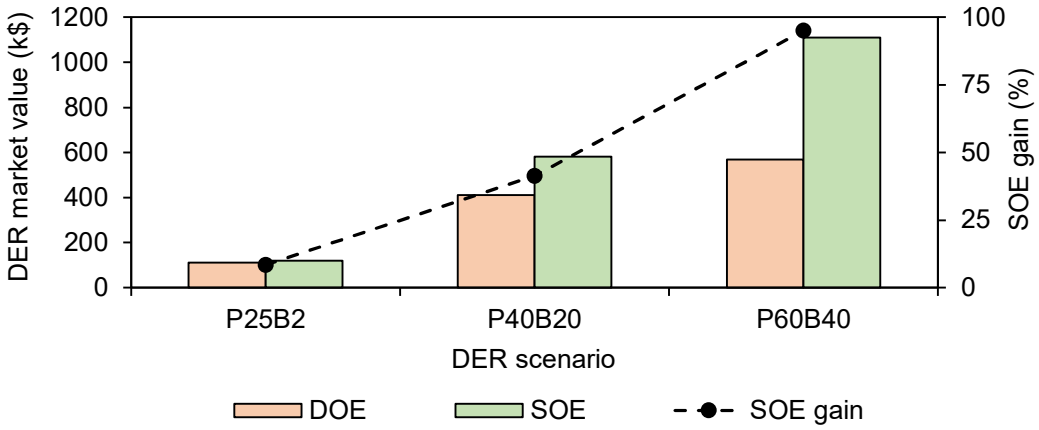


Figure 8. Unlocked DER value under SOEs and DOEs.

However, as discussed in the "consumer side" section of this report and the social science report [4], it is not a given that this will happen. VPPs are a niche technology. Even the Converge participants, who all had both a battery and an aggregator, were not using their batteries in a way that enabled SOEs to create grid value. Therefore, if taken as a whole, SOE technology is likely most suitable for a future where VPPs to scale become common.

3.2 What parts of SOEs were most valuable?

For more information

See *"Shaped operating envelopes: Technical Design and Implementation Report* [1]*"* for discussion of load forecasting (section 3) and automatic demand response procurement (section 5)

SOEs are not a single monolithic technology. There were two constituent parts of SOEs which warrant consideration separately:

- The automated procurement of network support, and
- The provision of individual participant load forecasts.

Automated network support procurement

As discussed earlier, network support was the only way that the SOE engine could alter participant generation and demand. In the Converge trial this was a constraint that significantly reduced the extent to which the algorithm could manage network congestion. However, the trial did show that automated procurement of network support was a useful tool for grid management. An example of this is in the "Real-time RIT-D" demonstration.

The Real-time RIT-D demonstration was a test of whether demand response procurement framework built during the Converge trial was able to be used to explicitly weigh network and non-network options to resolve network constraints. Although a proof of concept, the

scenario tested showed up to $1.9m of network benefits through the use of demand response instead of network augmentations[1].

The “includes zero” design principle in SOEs severely limited the extent to which automatic procurement of network support could manage grid constraints. Although whether this principle is still relevant is a worthwhile consideration for scaling of SOEs, it clearly aligns strongly with participants’ expectations around how they would like their batteries to operate. Potentially another relevant question is whether SOEs in their current form are the right tool for procuring demand response services. Online analysis and assessment of network support capabilities and needs clearly does work and may warrant consideration separate from SOEs alone.

Participant load forecasts

The SOE approach requires aggregators to provide 15 minute ahead forecasts of consumer demand. This enables the SOE engine to allocate capacity to those who need it. Aggregators can account for uncertainty in their forecasts by offering a range within which they expect customer demand to fall[2].

Creating accurate forecasts is inherently challenging, and this was confirmed during the trials, particularly when participants were generating. Inaccurate forecasts were a main cause of envelope non-compliance. But it appears that the inclusion of forecasts improves the outcomes of capacity allocation as capacity can be allocated to people who need it.

Higher quality load forecasts would improve SOE outcomes. But also, consideration of how uncertainty can be translated into envelopes would enable participants to comply with their envelopes more often. Improving load forecasts may require additional disaggregated behind-the-meter metering of devices like batteries and solar generation.

[1] In this simplified analysis only online tap changing transformers were considered as network augmentation options

[2] Although in the Converge trial aggregators provided a point forecast instead of a range.

4 Social systems and consumers

This project included social research to ensure there was understanding about how SOEs might be received in societal systems and by consumers. As all technologies are ultimately social, they need people to apply them and to be engaged with them.

Converge trialled an emerging technology, one that is being developed in a protected 'niche', not yet used by the whole of society. In our research we sought to understand what this technology did within the niche, and thus anticipate what it would be like if this technology was applied in society. To do this we spoke with stakeholders[3] of the energy system who would be involved in moving an operating envelope technology from niche to scaled. We also spoke to the Converge team, in part so we could weave in social and technical insights as we went and in part because it included intermediaries who might be involved in moving forward the development of SOEs. The team included, for example, innovators and aggregators, and people skilled at helping to communicate the technology to a broad audience.

Consulting energy consumers is always important as it helps us understand ultimate impacts and acceptance potential for technologies. We therefore sought to engage with a range of people with diverse experiences of energy, and with different access to distributed energy resources – including people experiencing the new niche technology being tested (in this case SOEs) and those who did not.

The topic was a complex one and so we sought iterative and emergent understanding by capturing and weaving in insights from different steps of fieldwork over time. This allowed us to learn from each step as we proceeded, which helped us explore and navigate through the complexities at hand.

Our social research sought to understand:

- responses to SOEs as an idea and as trialled,
- participation with SOE trials,
- intermediaries (stakeholders likely to be involved) and their societal roles and responsibilities, if SOEs were to scale further, and
- conditions with which householders would engage their DER with grid integrated systems.

Here we relay some overarching insights developed and explored via the social research report.

4.1 Relevance of, and interest in, SOEs – what did participants think of SOEs?

[3] stakeholders are called intermediaries in strategic niche management studies of technologies

It is widely expected by the industry that in the future there will be much more coordinated DER or DER that dynamically responds to market price signals [13]. Stakeholders with intermediary roles in operating envelope management and energy futures anticipate that DOEs will increasingly be introduced into management of networks in Australia. DOEs offer assistance with pressing capacity management issues and have been included in large scale trials, in solar PV export management strategies in South Australia and in new energy demand management requirements in Queensland. SOEs are an option in the evolution of operating envelopes and were broadly expected by stakeholders to be more in demand in the future when DER proliferates.

Overall, both stakeholders and consumers could see the benefits of SOEs as a concept. Householders and stakeholders alike saw the logic behind DOEs and SOEs and liked the idea that SOEs help to consider consumer preferences. DOEs as solutions came from a network need, which was acknowledged as important, but participants could see the added benefits of SOEs. Indeed, several stakeholders found it surprising that features of SOEs were not being factored into DOEs. In other discussions with people working in the energy innovation space, they explained that aspects of SOEs were being considered as DOEs, or similar strategies at the time, and were being developed and tested.

Householders with aggregators were minimally impacted by the trials. As SOEs were still in development and not widely applied as yet, all participants noted they would need more information before making a final decision about them.

4.2 Complexity and communications

SOEs are a complex and developing technology that is likely to be hidden within other products and systems. Communicating the unseen is difficult. Communicating complex technology which is unseen is even more difficult. Effectively explaining this technology to a broad audience poses problems because of both its complexity and it early stage of development. Nonetheless finding ways to clearly communicate this technology was necessary to help the consumer consider it and provide feedback.

Striking the right level of detail when it comes to communication helps to builds trust with the consumer. We worked to ensure SOEs were explained to participants in the short times we were with them before we sought feedback. Both stakeholders and householders understood our messaging but said more detail would be required to fully understand the implications of SOEs, for them and others. Householders sought more information on how SOEs would affect them, support their energy use and management processes, and align with their values. Stakeholders were interested in similar issues and also wanted to understand how SOEs would fit into the current system, who would be responsible for them, whether regulation was needed, how they would work in detail, and more.

Industry and consumers alike are on a maturity journey, one in which it is incumbent upon the electricity sector to find ways to communicate information to householders on how their consumer energy resources are being used and the impacts of this. Additionally, stakeholders across organisations involved with applying or observing and assessing operating envelopes also need to talk and collaborate. This suggested that joined-up approaches to communicating to consumers and between actors involved (who may be in industry, government, civil sector and other sectors) is needed. With coordination messaging can be consistent and clear.

4.3 Values and drivers of participation

Values held across the community/public prove useful to understand when seeking to identify the electricity system the Australian public wants and what may drive CER owners to participate in a future grid that includes new technologies and solutions. In our interviews with householders, the top 4 values that arose were social equity, environmental stewardship, self-consumption, and affordability.

> *"This is what society's about, making sure that you do help out, so electricity demand should be no different from making sure people don't starve or sleep on the street. If you can help out you should be able to help out." (Householder interview, 24/11/23)*

Social equity is a value important to many, as the above quote testifies. People care about their communities and would like to see the needs of the more vulnerable members of society looked after.

Affordability is a key aspect, and often drives, householder decisions. Financial viability and ensuring affordability of energy plays a large role in whether or not a household chooses to purchase CER. For those householders who could afford to purchase CER, care for the environment was often quoted as one of the contributing factors resulting in their purchase.

People are also passionate about self-consumption, its efficiency and its reliability. We have seen this borne out through social research in many DER/CER trials. The desire to self consume first, and ensure that there is enough energy left in one's battery to self consume at will, means that there may oftentimes be a clash between a householder's ability to make money on the electricity markets vs keeping excess energy stored in their battery for the householder to self consume. For example, there is an unforeseen electricity outage or a change in the householder's regular use of electricity.

When considering the SOE technology, broadly speaking the participants value what it is trying to do. They supported propositions to incorporate CER owners' perspectives into the operating envelope framework and to reduce solar 'wastage' by maximising the amount of rooftop solar generation that could be 'shared' back to the grid. However, there are particularities around these points that matter. For instance, it is not currently clear exactly which types of CER owners' perspectives or interests will realistically influence the operation of SOEs. The key outcome is that our research indicates that householders are likely to conceptualise having their "preferences incorporated into SOEs" much more broadly than industry does, thus providing fertile ground for misunderstanding, disappointment and distrust if not carefully and pre-emptively addressed.

"This idea (SOEs)...makes me morally uncomfortable because I feel like people with solar PV are going to become this privileged class, people who don't have solar PV are just going to be left with having to be price-takers and have no role." (Householder workshop A, 26/11/23)

Another householder highlighted the social equity risk that policies to incentivise individualistic approaches (such as installing rooftop PV and batteries) may unintentionally lead to an outcome that is detrimental for the broader community.

4.4 Who should benefit? The energy system as a collective good?

Some householders that we interviewed were happy to generate income with their excess solar via aggregation services. There was much interest by multiple householders in sharing energy locally, within one's own community. However, there were questions as to whether the local community or energy corporations would be the real beneficiaries.

4.5 Intermediary (stakeholder) involvement

The energy industry and related sectors (such as government) is on a maturity journey within the energy transition and there is a need for skills development and an expansion of knowledge within the industry.

The interim social report relayed various considerations about roles and responsibilities. This consideration must include identifying roles and responsibilities relating to regulations, checks of systems and technology implications, consumer rights and technology function tests and more.

Aggregators as existing agents for their customers seemed to allow a calmer space for householders to consider SOEs, as SOEs were but one extra aspect to an existing relationship (rather than a whole new relationship) and the base technology involved was familiar (as many had had a battery for a number of years). Previous DER integration trials have identified that anxiety can rise when complex technologies are new and their function and impacts are not fully understood. When understanding and testing of impacts takes place by people, their anxiety seems to settle down somewhat. Home batteries have been around for some time now so the familiarity with the technology is better, and there is a higher proportion of long-term relationships with aggregators.

Aggregator as agent of SOEs could work technically and is also possible from a social perspective. Established aggregation service relationships have great potential for add-ons that can enhance their products. The expertise of aggregation services is recognised by their customers but is not fully appreciated by people external to those companies. Additionally, we anticipate that aggregators need to be further consulted in any scaling activities to establish whether they are interested and able to take part in all aspects of critical application of SOEs.

4.6 SOEs as features, features of a product, a whole product or products?

SOEs nest with, and overlap with, other solutions that assist with CER integration into the grid and with capacity management of electricity by networks. The design particulars of SOEs will matter so they can work with other solutions and scale effectively. Consistency across the nation is important.

SOEs as a concept and a product have value that overlaps with processes elsewhere. For example, in stakeholder interviews people told us that there were elements of SOEs currently being considered or implemented in DOE trials and operational implementations.

In the final social research report we listed features of SOEs to better understand what SOEs offer householders and others. As currently designed the density and way they are applied perhaps hides the features and means we don't fully understand the value they may offer. There is further work to be done working out the benefits of SOEs for different cohorts. Related to this, householders wanted to understand the differentiated impacts of SOEs on CER owners. In particular what are the different impacts of SOEs on householders:

- with smaller or larger systems,
- with older or newer systems,
- living in suburbs with newer or older network infrastructure (and thus varying constraints), and
- living with particular vulnerabilities that impact their energy needs.

Those already with an aggregator may be less concerned about the SOEs as a product as their aggregator has already committed to a certain relationship with them and it has been tested.

It's the *how* of applying SOEs that is now of interest moving forward. Will aggregators be happy to embed these? Will householders understand what they do? We anticipate that there will need to be some interrogation of SOE features and consideration given to whether SOEs are part of a product or a full product of their own, and how they will interact with other solutions at a national scale.

4.7 Participant financial and technical participation experience

Participants in this trial were subject to SOEs for only a short time. The spread of dispatch across time, energy, and number of dispatches is shown in Figure 9. Clearly there was a different experience for different participants, and a notable difference between the experience of customers of the two aggregators, particularly in number of dispatches. This was related to the way that each aggregator enabled participation. There were different offer prices between them, as well as different constraints applied on participation. One of the two aggregators who offered an upfront $200 participation incentive and placed a cap

on the amount of network support per customer, while the other paid participants $1/kWh for network support.

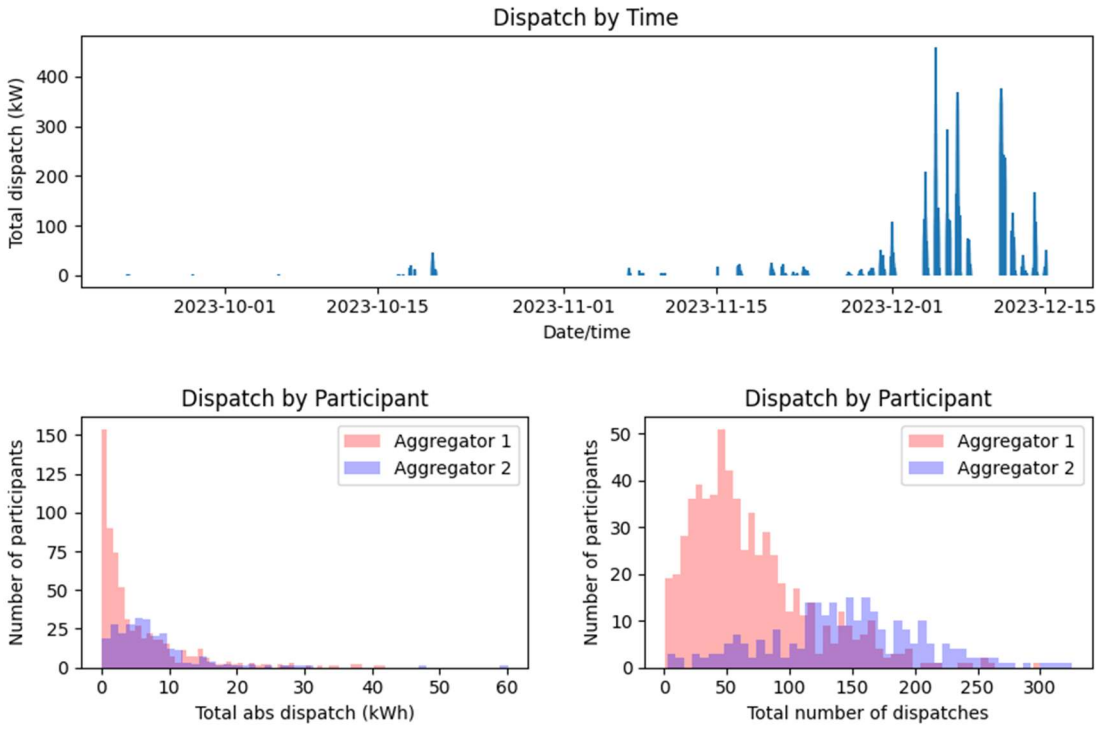


Figure 9 SOE operation for participants by time, energy, and quantum

Participants from the two aggregators provided different levels of network support and were paid differently. Because aggregator 2 paid upfront their network support was used more often as there was no incremental cost for using it. The level of participation (in terms of battery energy) and participant payments is shown in Table 2.

Table 2 Participant battery usage and payments

Aggregator	Amount of network support	Payment
Aggregator 1	**Min:** 0kWh **Median:** 2.55kWh **Mean:** 5.13kWh **Max:** 42kWh	**Min:** $0 **Median:** $2.55 **Mean:** $5.13 **Max:** $42 All paid at $1/kWh
Aggregator 2	**Min:** 0.69kWh **Median:** 6.05kWh **Mean:** 7.33kWh **Max:** 60.09kWh	All were paid $200 Effective payments between $289 and $3.32/kWh

A sample of participation envelopes for a single time period is shown in Figure 10. This figure was produced during a trial period when all 1001 customers were artificially mapped onto a single feeder to test the effects of high numbers of DER. As such, many, but by no means all of the envelopes are quite restrictive. Clearly there was significant diversity in envelopes, with some very large and others small. This reflects the different grid conditions each of these participants were subject to. Also clearly visible is that most participants were self-consuming (as shown by the blue bars), but were offering significant network support. Also visible is forecasting errors, as several of the red bars (the actual behaviour) diverged significantly form the forecasts even in the absence of network support dispatch.

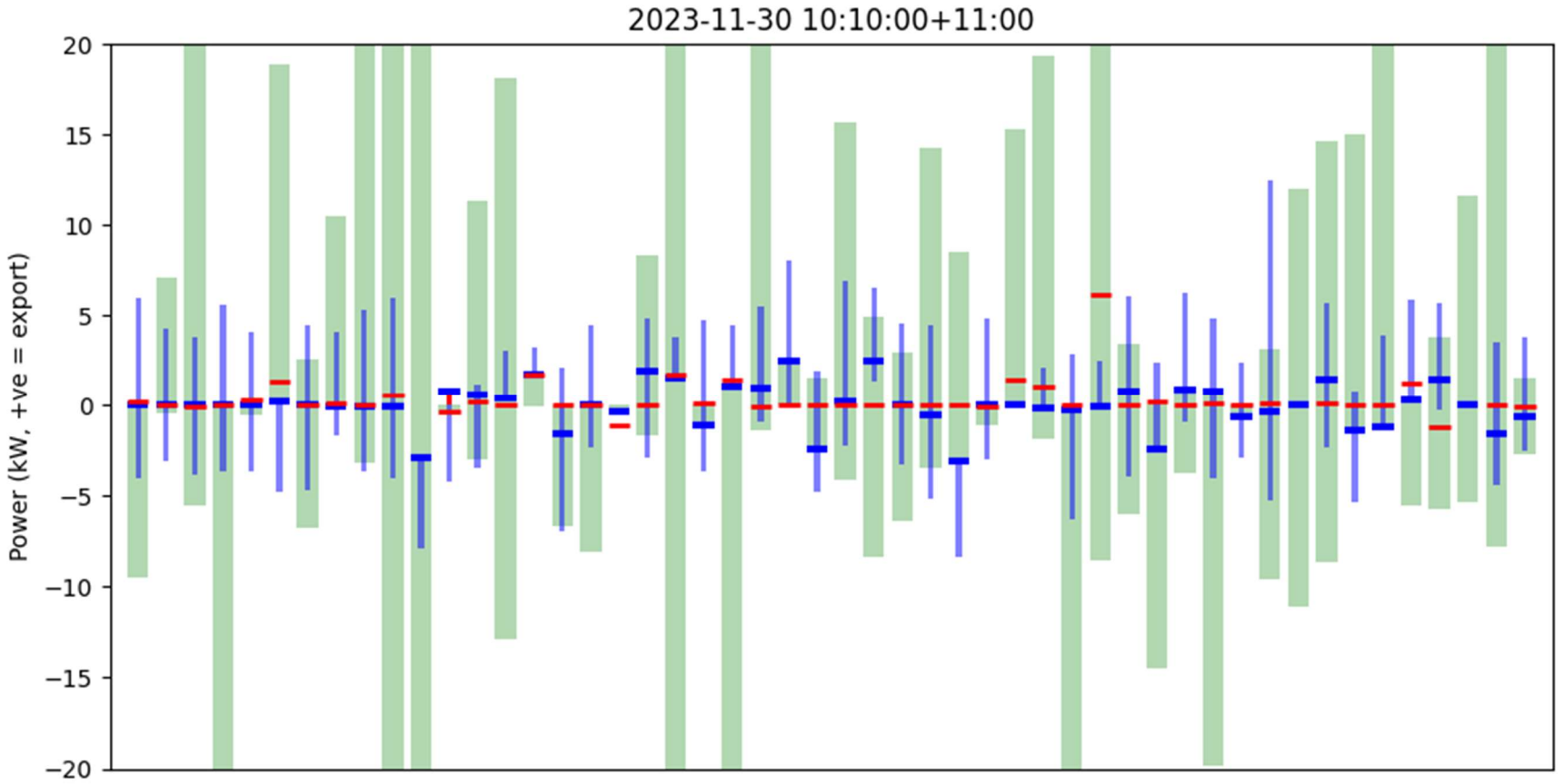


Figure 10 Envelopes from a selection of customers for a single time period in the "high concentration" test

4.8 Scaling and implementation and what is next?

The social science report made five main recommendations:

Responding to values in technical design of SOEs

Values can and should influence how technology is built and developed. The inclusion of self consumption in the SOE engine itself is a real demonstration of this. People had other values too. These are described further in **Error! Reference source not found.** and **Error! Reference source not found.**. These values can and should influence the design of the SOE technology. For example, as described in the technical report [30], equity was not explicitly considered in the SOE algorithm as built, but our participants strongly felt it should. Similarly climate drivers and affordability were key values householders were considering.

Pay mind to complexity

Although the prospect of the additional consideration of consumer needs underpinning SOEs was attractive to many, the decision to scale SOEs needs to be taken in the context of the additional complexity it creates. It may be that when taken in the context of the additional effort in SOEs that they will need to be simplified or implemented in parts.

The implementation model is yet undefined

Although we can say that SOEs appear to be best applied as a relationship between DNSPs and aggregators, many important implementation details remain untested. There was diversity in how SOEs were offered to customers in the trial, and the Converge implementation of SOEs was quite different to the way DOEs have been applied elsewhere. This will require definition for future application.

Supporting and defining the role of intermediaries

Customers of aggregators we spoke to were generally relatively comfortable with their relationship with their aggregator, although they did have specific feedback on communication and how they managed competing interests. There were also questions whether the inclusion of aggregators in SOEs was strictly necessary at all.

Intermediaries are clearly important for the scaling of SOEs. While the role of aggregators has been explicitly considered to date, the important role of other intermediaries has not been explored in detail. This will need further consideration as SOEs are further developed.

SOEs are a small part of a big picture for householders

Householders are not likely to be considering SOEs alone. Consideration will mostly be within the context of a larger decision making framework. For example, considerations around whether to buy a battery, participate in a VPP, or buy an electric vehicle. This means communication with householders needs to be framed within this context.

5 Recommendations for the role of SOEs in the future grid

Based on our trial findings, Figure 11 shows the role we expect SOEs might play in the future. They are primarily a way of formalising the relationship between DNSPs and aggregators. This is based on our findings that:

- SOEs work best when devices are interacting dynamically with the energy system as would commonly be found in a VPP, and
- SOEs alone are likely not enough of a reason for a consumer to add the complexity of an aggregator relationship.

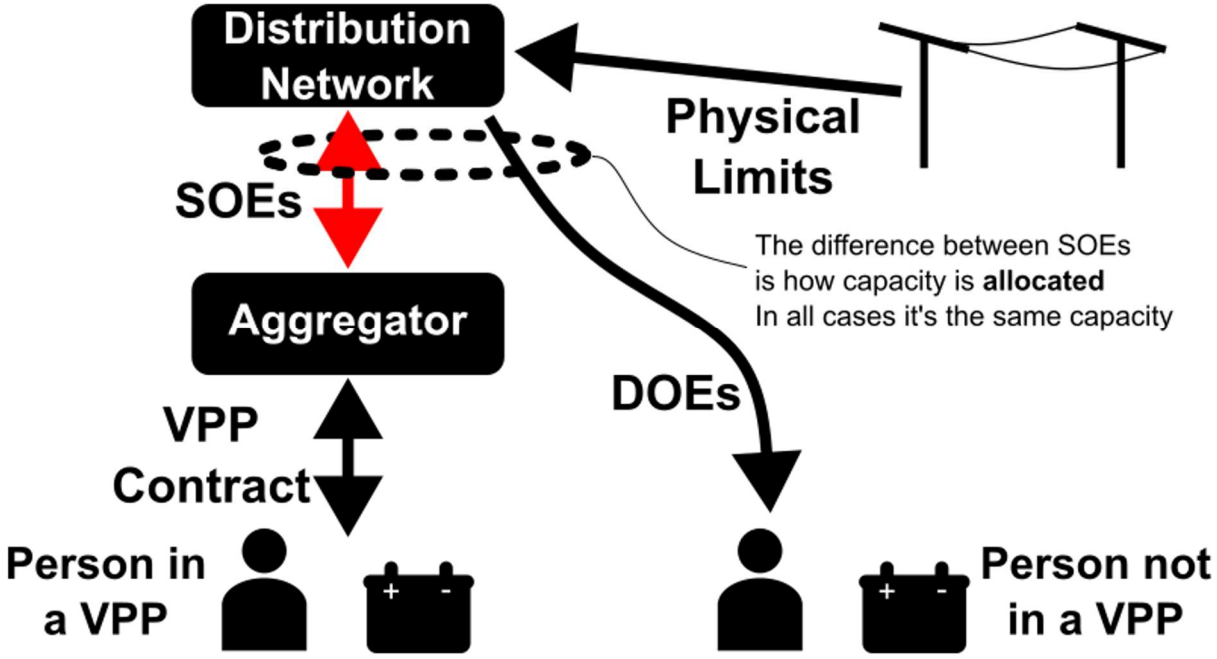


Figure 11 A potential future for SOEs

SOEs had their genesis in an expectation that future dynamic use of DER to participate in markets could cause grid congestion. Converge only tested part of that picture as participants weren't using their batteries to dynamically respond to market price signals, thus only part of the anticipated value of SOEs was realised.

It is widely expected by the industry that in the future there will be much more coordinated DER or DER that is dynamically responding to market price signals [13], which sets the expectation that even if SOEs are not required today they may be in the future. Although our trial and others [12] have shown that battery owners may not be as receptive to full market participation as is expected by industry stakeholders today. Therefore, we expect that many future owners of flexible devices may prefer not to participate in a VPP thus will not use their devices in a way that requires SOEs.

In the Converge trial most participants saw only very small changes to their battery behaviour. And particularly in the case of the participants who where customers of the

aggregator that paid incentives upfront, they received a large incentive for the amount of change they saw. But still participants we spoke to were generally satisfied with their participation. Partially this was related to the fact that the SOE algorithm allowed for self-consumption which was a key driver for them to get a battery in the first place. Therefore, it seems that if the participation experience for Converge holds in future rollouts of SOEs, the impact may be small enough that many consumers do not notice them.

5.1 SOEs are part of the DNSP – aggregator relationship

Finding: SOEs are part of the DNSP – aggregator relationship

SOEs may be most beneficial if they are part of aggregator VPP products in the future. This enables aggregators to build them into products for those consumers who desire market participation. Consumers who do not desire market participation through VPPs will likely remain on DOEs.

Industry will need to work together to standardise the underpinning DNSP/aggregator relationships that enable SOEs.

The decision to participate in DOEs is usually made as part of purchasing and installing a PV or battery system in the operational DOE schemes of today. This means the decision to participate in DOEs is not often made in isolation. It seems likely that decisions around future adoption of SOEs is likely to also occur in a wider decision-making context. For example, it is likely that participation in SOEs will be a consideration related to participation in a VPP.

People do have a choice about whether they adopt DOEs or not when they install a solar system. It is not clear if this will also be true for SOEs with VPP participation, or whether SOEs without VPP participation is possible. So, there are some unresolved questions:

- Can people participate in SOEs without an aggregator?
- Is participation in SOEs a requirement for enrolling in a VPP?
- Can people choose to participate in a VPP without also participating in SOEs?

The extent to which SOEs are connected to VPPs sets out requirements and expectations around how people become participants in SOEs. For example, existing communications relating to DOEs target both customers and solar PV installers, as people who are installing PV will always require a PV installer and DOEs are a decision related to PV installation. For SOEs, it may be that all people who are considering participating in a VPP should also consider SOEs, so aggregators become important parties in this discussion. This appears to be the most likely situation for most future SOE participants. Clear communication and communication channels are important, in particular because future implementations of SOEs may be asking people not to self-consume.

The two participating aggregators in the Converge trial created significantly different products to offer their customers. One opted their customers into the trial automatically but gave their customers the ability to opt out. One offered participation to customers and asked them to opt in. Similarly, one paid their customers a fixed amount upfront for participating, the other paid their customers for each event. A common finding across our

social research from participants with both aggregators was an expressed desire by participants to be better informed about SOEs.

This has important implications:

- For Converge participants, SOEs were an agreement with their aggregator, and
- Like network tariffs, aggregators built products on SOEs.

DOEs are part of connection agreements, therefore they are an example of a direct relationship between DNSPs and DER owners. It appears that in the future SOEs may be part of an agreement between aggregators and their customers and are therefore likely to be complementary to DOEs.

This means that future SOEs may be applied in a way more akin to network tariffs than DOEs. This makes SOEs a framework for creating products rather than a specific offer for energy consumers.

Enabling this will likely require some formalisation of the relationship between aggregators and DNSPs. The network support contracts formed as part of Converge were challenging to negotiate and bespoke. This is not likely to be a credible approach for a large-scale rollout. This framework is best defined in consultation with industry. As part of these discussions, considerations around information requirements needed to communicate the value of SOEs to consumers should be considered.

5.2 The role of values in SOE design

Finding: The role of values in SOE design

Consumer values are important inputs into the design of SOEs. The self-consumption design decision underpinning SOEs is a clear example of this. People ideated many other values to us in our social research and these could be inputs into further design to refine the SOE concept.

Part of values is consideration of how future participants will be able to see they have been met. This may require additional types of information to be communicated between DNSPs and aggregators.

The design decision that envelopes must enable self-consumption ended up being a clear demonstration of values and how they can influence the design of grid-side technologies such as SOEs. But it was also a demonstration that these values may be in tension with network management objectives, because of the profound impact it had on the amount of network support that could be procured.

Values were considered in the original technical design of SOEs in two ways in Converge:

- Equity was to be considered in capacity allocation, and
- Aggregators were expected to advocate for their customer's values in how they asked for capacity allocations and offered flexibility services.

Through the trial, the explicit consideration of equity was removed from the SOE capacity allocation engine because it was found to cause significantly more constraint – i.e. small numbers of participants with smaller envelopes (due to being subject to network constraints) resulted in more constraint for everyone because everyone needed to receive

similar envelopes. In this framing, equity could be said to be the situation where all people (of similar type) were subject to similar constraints. Participants in social science research also discussed equity with us. In fact, it was one of the most common values raised. They were concerned about differential impacts of SOEs on people in different situations who may be subject to SOEs such as those with smaller and larger systems, in older or newer suburbs, or on older or newer networks. But also, people were concerned about the impact of SOEs on people who can't participate in them, such as those with different flexibility capital[4]. So, it could be said that while equity as originally conceived in the Converge trial was around capacity allocation, for our social research participants it is more related to overall outcomes. For example, this might mean there is an expectation some consumers (such as those experiencing vulnerability, health services, and community centres) receiving larger capacity allocations because they need them more. There were other values discussed by participants too, including self-sufficiency, financial, community care, and environmental drivers. It may be that many of these are not easily translated by aggregators to the technical information needed by SOEs. These values often related to overall objectives rather than specific participation considerations.

Clearly values need to be considered within the overall structure of SOEs rather than by any one organisation in isolation. Tools such as value sensitive design [15] can help translate values into design parameters for technical approaches such as SOEs. These approaches will require industry to work together, as it may be that relationships need to change to enable these values to be realised.

In our social research people ideated values to us. As part of ideation, they also told us what realising these values might be like for them. Frames like Service Dominant Logic [16] tell us value is co-created with customers of an organisation. In other words, it says that more than SOEs doing things that align with their values, participants must also be able to see these things happened in terms that have meaning to them. One example of this was that many participants did want to support their local electricity grid. But they needed to see how their devices contributed to supporting the grid. This is relevant because only DNSPs know this information. Currently SOEs are designed to only communicate to aggregators capacity information, but not what comprises the limits. For aggregators to be able to tell their customers how network support was useful to the grid, this information must also be communicated by DNSPs to aggregators, or DNSPs must make this information available to participants themselves.

Clearly the role of values must be carefully thought out in technical grid side algorithms such as SOEs.

[4] "Flexibility capital" is a way of describing how people have different abilities to be flexible, related to their unique situation (such as comfort, health, income, living situation, family situation). Authors such as Powells and Fell describe this concept in more detail [14].

5.3 How SOEs could influence DOEs and other technologies

Finding: How SOEs could influence DOEs and other technologies

SOEs are a set of approaches. Taken as separate from SOEs themselves, they potentially can provide useful improvements to other processes.

- Better load forecasting can enable DOEs to be more reflective of consumer energy needs
- Demand response capacity data can improve planning processes and comparison of network and non-network options.

In this section of the report, we have so far mostly discussed SOEs as a whole (e.g. as a single approach which has specific use cases). But in reality SOEs are a collection of approaches. They aim to enable dynamic, price responsive DER to maximise their ability to participate in markets. But the various approaches also meet other needs that are valuable in isolation. This was echoed by industry stakeholders who spoke of how some of the SOE approaches were already being integrated into DOE approaches.

At a technical level, SOEs are an improved way of allocating network capacity. This improvement is enabled by additional information supplied by aggregators:

- Improved view of the participant's capacity needs in the near future,
- A view of the participant's future market bids, and
- A view of participant's availability to support the grid.

These are not necessarily mutually exclusive with other approaches being considered in concert or parallel with SOEs. There were two main themes that emerged from Converge:

- Better load forecasting, and
- The value of knowing about what flexibility is available.

The DOE engine used for comparative purposes in Converge did not specifically consider consumer intent, it more simply shared capacity allocations based pro rata on standing data (e.g. PV system size). Aggregators undertook load forecasting in the SOE algorithm. However, it need not be the aggregator making these calculations. When we spoke to stakeholders they told us that higher fidelity load forecasts were already being developed and integrated into DOEs. These approaches would capture some of the benefits of SOEs into DOEs, particularly for DER owners who are not intending to provide grid services.

From a network support point of view the Converge trial showed that at least without dynamic prices and control of PV, SOEs were not very effective ways to procure network support services. However, in this process they built an extensive view of network support capability. This data was then used in the "Real-Time RIT-D" tool to investigate the economics of network vs non network solutions to grid constraints. The "Real-Time RIT-D" tool shows that data collection is a useful process in itself, particularly when it is data of the sort not commonly collected to date.

Alternative network support approaches exist (such as real-time pricing as is being demonstrated by Edith [17]). Demand response capability collection mechanisms such as

demonstrated by Converge can complement these approaches by collecting data that networks can use to better plan their networks.

SOEs were proposed as a development of DOEs. This was also how we discussed them with participants in our social research. A recurring theme was in the level of complexity in the SOE algorithm compared to the simpler DOE and FOE approaches. It appears from the modelling that SOEs do provide a better financial outcome than DOEs when there are many devices participating in VPPs. However, it is not clear when or if these conditions will be realised. There is not a binary difference between SOEs and DOEs (as found in our stakeholder interviews). In considering how SOEs scale, the component parts should also be considered separately to determine the best mix of approaches that achieve the desired outcomes

5.4 The role of aggregators, solar installers, and other key intermediaries

Finding: The role of aggregators, solar installers, and other key intermediaries

Intermediaries will be important in the scaling of SOEs. Aggregators are a key intermediary – particularly given SOEs are likely part of VPPs in the futures.

Other intermediaries will also be important such as DNSPs, early adopters, solar installers, and family friends. As the concept of SOEs is further developed, their parts in intermediating SOEs should be further defined.

As discussed above, if adopted in the future, SOEs may become a relationship between aggregators and DNSPs. This means aggregators are an important intermediary in the uptake and operation of SOEs. However, this doesn't mean there aren't also other important intermediaries such as solar installers, early adopters, battery companies, consumer advocates, and regulators whose roles cannot be forgotten.

Participants in our research who were customers of aggregators had grown more comfortable with the way aggregators operated their DER over time. Although it is important to note that all participants were on relatively predictable standard retail tariffs, which led to relatively predictable battery behaviour. For participants, SOEs were relatively hidden among the day-to-day operation of their battery. This validates aggregators as important intermediaries in SOEs.

Other intermediaries are also important. For example, the designers of the SOE engine intermediated self-consumption values into the design of SOEs. People also spoke of other intermediaries such as solar installers, early adopters, governments, DNSPs, and others. Mapping intermediaries and their roles more completely as the finalised view of SOEs is built will be an important task for successful scaling. This map must include roles beyond technical. For example, early adopters, solar installers, family, friends, and existing SOE participants have a major role in the uptake of technology today and will similarly have a major role in the uptake of SOEs.

5.5 The use of data and information

Finding: The importance of data, information and transparency

Technical data is important to SOEs. This includes how the network is configured and its current state. Initiatives to install devices that collect more data should be continued.

Participants in our research also expressed a desire for transparency, or an 'opening up' of the operation of the SOE algorithm so they can see why their devices were being operated as they were.

Data quantity and quality caused challenges for the operation of the SOE algorithm. Quality network configuration and real-time state data is needed for the algorithm to operate effectively. This aligns with the findings of other DOE trials [18], and leads to one of the key recommendations of the technical report being that the data collected by additional network monitoring and smart metering will be important. Similarly, it will be important for networks to increase the quality of their network models, as these are the basis for the operation of the algorithm.

Clearly data is critical for networks to adequately assess their capacity. Our social science research also discussed what future participants would like to see from SOEs. Householders expressed desire to understand how their contribution has helped the grid. This indicates that an 'opening up' of the operation of algorithms such as SOEs to householders may be appropriate. This may require changes to the algorithm itself so that this information can be communicated to participants.

5.6 Communications

Finding: the importance of communication

The energy sector is shrouded in mystery for most consumers. It is important that the sector brings the consumer along on the evolving energy transition journey. Of particular importance is communication that is consistent, clear, and targeted. Effective joined-up communication within the sector could help drive the energy transition and give householders agency to better utilise their DER as they see fit.

To assist consumers to make informed decisions that involve the use of their DER, a coordinated communications campaign could be beneficial. For example a campaign that explains how DER and operating envelopes are being applied and the important role that householders play in driving the energy transition. Our social research revealed, for example, that some people wanted to share their excess energy with others. Others might consider sharing their excess energy if they could be assured that their energy needs are adequately met first. There is a communication/education piece that could be considered to assist with transparency and greater understanding.

6 Bringing it together – what's next?

The Converge trial tested Shaped Operating Envelopes. It created a niche and tested a particular view of how aggregators and DNSPs might work together in the future to manage network capacity while enabling market participation by DER. As is expected in a trial, some things worked well, some still need to be further developed. This section is a summary of the findings described in 5.

Finding: SOEs are part of the DNSP – aggregator relationship

SOEs may be most beneficial if they are part of aggregator VPP products in the future. This enables aggregators to build them into products for those consumers who desire market participation. Consumers who do not desire market participation through VPPs will likely remain on DOEs.

Industry will need to work together to standardise the underpinning DNSP/aggregator relationships that enable SOEs.

Finding: The role of values in SOE design

Consumer values are important inputs into the design of SOEs. The self-consumption design decision underpinning SOEs is a clear example of this. People ideated many other values to us in our social research and these could be inputs into further design to refine the SOE concept.

Part of values is consideration of how future participants will be able to see they have been met. This will require clear, targeted and transparent communication with consumers. It may also require additional types of information to be communicated between DNSPs and aggregators.

Finding: How SOEs could influence DOEs and other technologies

SOEs are a set of approaches. Taken as separate from SOEs themselves, they potentially can provide useful improvements to other processes.

- Better load forecasting can enable DOEs to be more reflective of consumer energy needs
- Demand response capacity data can improve planning processes and comparison of network and non-network options.

Finding: The role of aggregators, solar installers, and other key intermediaries

Intermediaries will be important in the scaling of SOEs. Aggregators are a key intermediary – particularly given SOEs are likely to be part of VPPs in the future.

Other intermediaries will also be important though such as DNSPs, early adopters, solar installers, and family friends. As the concept of SOEs is further developed, their part in intermediating SOEs should be further defined.

Finding: The importance of data, information and transparency

Technical data is important to SOEs. This includes how the network is configured and its current state. Initiatives to install devices that collect more data should be continued.

Participants in our research also expressed a desire for 'opening up' of the operation of the SOE algorithm so they can see why their devices were being operated as they were.

Finding: The importance of clear, consistent and targeted communications

The energy sector is shrouded in mystery for most consumers. It is important that the sector brings the consumer along on the evolving energy transition journey. Of particular importance is communication that is consistent, clear, and targeted. Effective joined-up communication within the sector could help drive the energy transition and give householders agency to better utilise their DER as they see fit.

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