Converge Social science - final report

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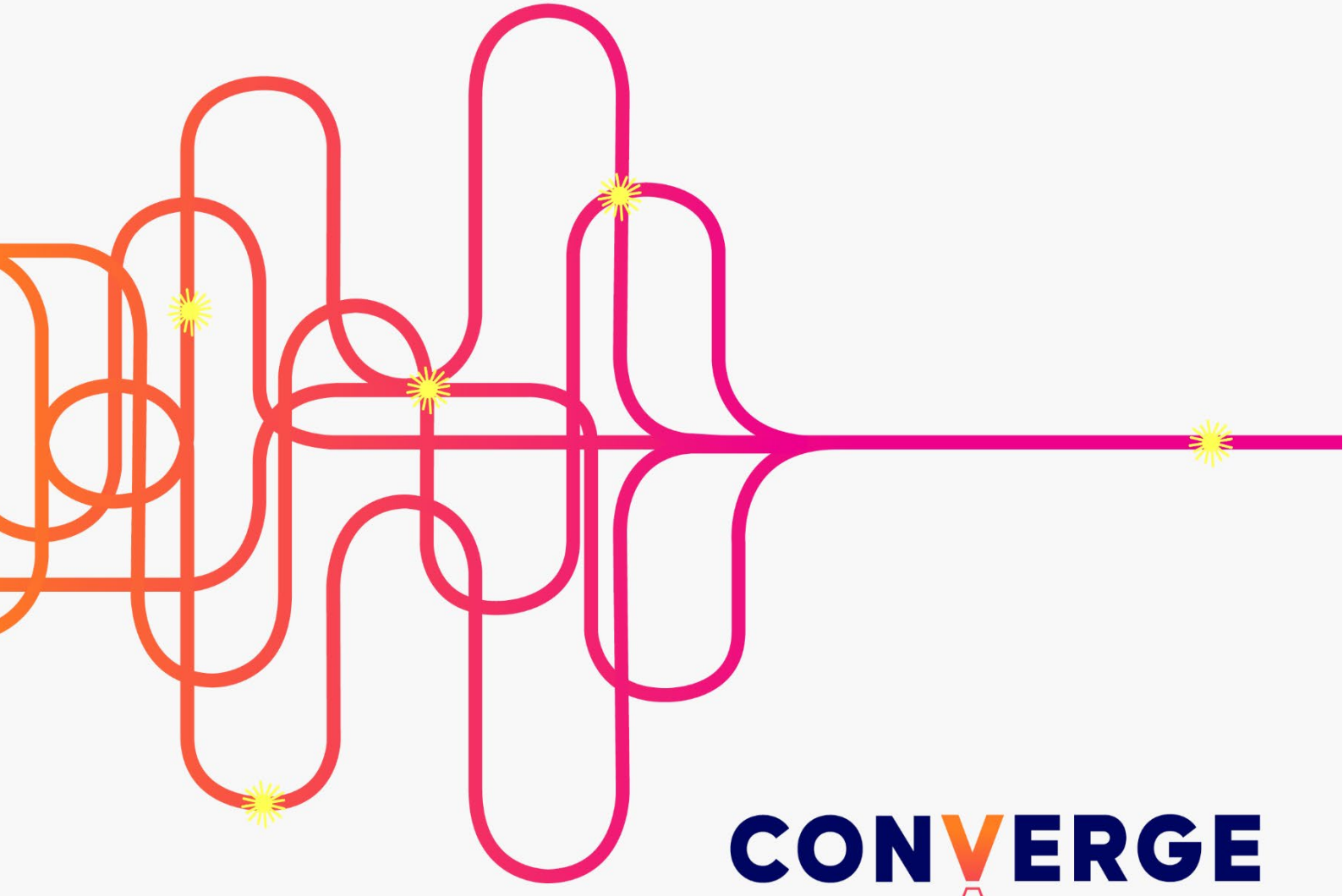

CONVERGE

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Executive Summary

Project Converge was a two and a half year trial that involved implementation and testing of a new concept called Shaped Operating Envelopes (SOEs). It included two streams: technical development and demonstration of SOEs; and social science research to understand consumer and stakeholder expectations and views on SOEs. This report relays the findings from the social science research stream.

Project Converge developed a new platform to improve electricity supply capacity management in conjunction with distributed energy resources. This new technology has been called shaped operating envelopes (SOEs) and is an evolution of previous dynamic operating envelope (DOE) approaches. SOEs use new processes as a 'technology' to integrate aggregation services, and factor in what aggregators know about consumer energy and DER use in real time capacity allocation processes. The intention of SOEs is to support more effective use of network-supplied electricity.

This social research examined both specific reactions to SOEs and other influences on SOE development, implementation, and scaling. Additionally, this research also captured insights about DOEs and their application alongside SOEs. Dynamic operating envelopes, currently only in their 3rd year of application in Australia, have had little social investigation to date.

This, the final, report is the second of two socially focused reports produced for the Converge Project. The first described intermediary insights on dynamic and shaped operating envelopes. This final report contributes findings captured throughout the social research and contributes insights that support further development of SOEs (or aspects of them), understanding of DOEs and their interrelationship with SOEs and grid integration of consumer DER as it relates back to operating envelopes. To this end we ask:

> What key design and implementation factors emerged about operating envelopes, especially DOEs and SOEs, and about grid integrations of DER with operating envelopes, from Project Converge social research?

Findings from this report are intended to be of use to designers and developers of DOE and SOE technical solutions, end users of the SOE technology (for example, organisations providing aggregation services), and stakeholders involved with DOE and SOE application.

The social research approach used for this project is underpinned by a set of propositions, in particular that:

- All technologies require people to apply them and to be engaged with them.
- This is a trial of an emerging technology, that currently is being developed in a protected 'niche'.
- Stakeholders of the energy system – intermediaries - will be involved in moving a technology from niche to scaled.

- Including energy consumers - both those experiencing the technology and those who are not yet - is always important for new DER technologies.
- We sought iterative and emergent understanding by layering up insights from different steps of fieldwork and capturing different perspectives over time.

Related to the propositions above, this research used mixed qualitative methods, underpinned by strategic niche management and sociotechnical research approaches. Findings have been compiled through a series of interviews, group discussions, and contextual observations with stakeholders. Insight was gathered from 58 participants: 22 energy system stakeholders (intermediaries) with some current or potential relationship with operating envelopes and 36 householders (energy consumers) with and without connections to SOEs, including some long term battery owners. The SOE design and testing team (who came from all the organisations involved in the trial) also participated in social research. Engagement with participants occurred mid-2022 to February 2024 within the trial period which ran from November 2021 - March 2024.

Project Converge's social research revealed many useful insights. Five main findings are described here as guides for the next stages in SOE design and development. These are:

- Responding to key **values** of those involved is important to acceptance;
- **Complexity** that extra SOE processes can create needs consideration;
- **Implementation pathways** need further exploration and definition;
- Supporting and defining the role of **intermediaries** that will be involved with SOEs is important; and
- SOEs are a **small part of a big picture** for householders.

In line with other research, **values** of users need to be factored into design of technical algorithms to enhance applicability and acceptance. So, continuing to design in (respond to) consumers and organisation values in the technical design of SOEs is key. An example of values in SOE design is in the ability for householder to self-consume solar energy generated before other SOE actions occur. The algorithm enables self-consumption, which causes a tension between self-consumption and grid benefits. Social equity was another value intended to be considered in the SOE algorithm but implementing equitable processes (as designed) caused issues with the operation of the algorithm. Participants raised equity, self-consumption, environmental, and financial values as driving their decisions. Indeed, the concept of SOEs was attractive to people because SOEs could consider the needs (values) of people. Householders are likely to conceptualise having their preferences incorporated into SOEs much more broadly than designers and implementers of SOEs would, providing potential for misunderstanding, disappointment and distrust if not carefully and pre-emptively addressed.

The decision to scale SOEs needs to be taken in the context of the additional **complexity** it creates on top of other network capacity management processes. Complexity of orchestration and capacity management altogether is likely to affect application and scaling. It may be that when taken in the context of the additional effort required of householders to engage with SOEs or where complexity is otherwise a barrier, SOE functions could be applied as elements or parts

of other functions. This suggestion is made because various elements of SOEs as component parts have been identified as applicable and useful in and of themselves.

Well prepared and curated communication can assist and be an antidote for complexity in various instances. Stakeholders and householders involved do require understanding of various key points and implications of engaging with DER grid integration solutions and operating envelopes. Coordinated communication is needed and this will require consumer insight and multiple intermediaries to have input.

SOEs were applied in Converge via a relationship between DNSPs and aggregators as this seemed the best **implementation pathway**. However, SOEs do not as yet have well defined implementation pathways and important implementation details remain untested. Aggregators chose different application methods for SOEs, demonstrating diversity in how SOEs were offered to customers in the trial. This highlighted the potential for SOEs to be applied in different ways. DOEs are also being applied in various ways nationally. Implementation pathways and their implications from both systems and social points of views need further definition and testing.

Intermediaries are clearly important for the scaling of SOEs. Supporting and defining the role of intermediaries that will be involved with SOEs is therefore important. Aggregators are key intermediaries for SOEs in this trial. Customers of aggregators we spoke to were relatively comfortable with their relationship with their aggregator, although they did have specific feedback on communication and how competing interests were managed. There were also questions from other intermediaries about whether the inclusion of aggregators in SOEs was strictly necessary at all. Additionally, how the broader group of intermediaries necessary for SOE implementation relate and interact with operating envelopes and with consumers will need further consideration as DOEs and SOEs are further implemented.

SOEs are a **small part of a big picture** for householders. Householders will likely consider SOEs as part of their broader decision-making frames and contexts. Multiple factors, including priorities related to values, will affect decisions about whether they take part in SOEs or not. Perceived trustworthiness of organisations involved is a factor, as is whether they care to engage with new organisations, spend the effort, understand SOE processes, and how comfortable and secure they feel. For example, SOEs may be considered in the context of whether consumers prioritise and buy a battery, participate in a Virtual Power Plant with a certain aggregation service, or buy an electric vehicle. Communication about SOEs with householders will therefore need to be framed within these contexts and consider how SOEs fit in the wider systems they interact with.

Further detail on findings is contained in the body of the report.

Contents

1. Introduction

This report relays findings of social research conducted as part of Project Converge. Project Converge developed a new platform to improve network capacity allocation in conjunction with distributed (often consumer) energy resources. This new technology has been called shaped operating envelopes (SOEs) and is an evolution of previous dynamic operating envelope (DOE) technologies [1], [2]. SOEs use new processes as a 'technology' to explicitly integrate aggregators and what they know about consumer batteries into capacity allocation processes. The intention of SOEs is to support more effective use of network-supplied electricity. The overall project included:

- design and development of a decision-making platform, called shaped operating envelopes (SOEs),
- testing of shaped operating envelopes with 1,001 household-based batteries over 2 months (eventuating in 8500 + network support events and 5.1MWh of response from batteries), and
- social research in parallel to development and trialling of SOEs.

All new technological solutions must be implemented in what are socially contrived and run systems and need to be engaged with by relevant stakeholders and consumers. Examining new technologies from a social perspective as they develop therefore captures understanding of factors that affect implementation. This social research therefore ran alongside technical development of SOEs to capture socially situated insights from people who would be involved in various ways with SOEs moving forward and who experienced SOEs during the trial.

SOEs as a developing technological solution sit within a wider, and very influential, context of transitions occurring with distributed energy resources (DER) integration and electricity supply capacity management. Distributed energy resources are also called consumer energy resources (CER) when behind-the-meter of households. Grid integration of DER and electricity supply management processes, including the evolution of operating envelope protocols and technologies to be more dynamic, will greatly affect the relevance of SOEs and the potential to further develop and scale them (or aspects of them). Consequently, this social research examined both specific reactions to SOEs and looked at other influences on SOE development, implementation, and scaling. Importantly, this research captured insights about DOEs and their application alongside SOEs. Dynamic operating envelopes, currently only in their 3rd year of application in Australia, have had very little social investigation. This social research, via engagement with relevant householders, energy system stakeholders, and the SOE technical design team during development therefore explored:

- operating envelopes evolution, including of DOEs and SOEs;
- opinions about and responses to SOEs; and
- related issues of distributed energy grid integration and operating envelope implementation.

This, the final report, is the second of two socially focused reports produced for the Converge Project. The first reported an overview of insights stakeholders (intermediaries) shared on both

DOEs and SOEs [3]. This final report contributes findings captured throughout the social research and contributes insights that support further development of SOEs (or aspects of them), understanding of DOEs and their interrelationship with SOEs and grid integration of consumer DER as it relates back to operating envelopes. To this end we ask:

> What key design and implementation factors emerged about operating envelopes, especially DOEs and SOEs, and about grid integrations of DER with operating envelopes from the social research for Project Converge?

Responding to this question the social report supports exploration of SOEs as a solution and as part of a broader national discussion about operating envelopes and their interaction with distributed energy resources (DER) and the energy supply transformation underway in Australia. Findings from this report are intended to be of use to designers and developers of DOE and SOE technical solutions, end users of the SOE technology (for example, organisations providing aggregation services), and stakeholders involved with DOE and SOE application.

Mixed qualitative methods were used in this research, underpinned by strategic niche management and sociotechnical research approaches. Insight was gathered from 58 participants - 22 energy system stakeholders (intermediaries) with some current or potential relationship with operating envelopes and 36 householders (energy consumers) with and without connections to SOEs, including long term battery owners. The SOE design and testing team (who came from all the organisations involved in the trial) also participated in social research. Engagement with participants occurred mid 2022 to February 2024 within the trial period which ran from November 2021 - March 2024.

This report:

- Relates methods and underlying guiding approaches in Section 2;
- Provides background by explaining the electricity system context that generated SOEs in Section 3;
- Sets out what SOEs are in Section 4;
- Relates findings useful for SOE development and DER grid integrated futures in Section 5;
- Discusses implications in Section 6; and.
- Outlines conclusions and where to next in Section 7.

2. Methodology

The social research for Converge applied multiple qualitative methods, that were applied in a staged and iterative way to ensure our understanding evolved emergently in response to previous insights gained. The multi methods included consultation via interviews and workshops with stakeholders involved with the energy industry with some relevant knowledge related to operating envelopes, householders (some with the trial and long-term battery owners and some not), and SOE design and development team members. We sought diverse points of views to assist in better capturing the many facets of the complex phenomena at hand more wholly.

2.1 Underlying propositions and theories

Particular propositions and theories underpinned our social research approach for this project. We step through some propositions and the related theories in this section to provide some background to the approach and methods we used.

All technologies require people to apply them and to be engaged with them.

This research takes the position that social research will help understand critical factors related to technology adoption. All technologies require people to design, build, implement and use them. As such people's positions, ideas, and responses to and about any given technology are important. The complexity of people's and systems' reactions to a technology can be better understood by capturing insight from people involved, especially when there is new, poorly documented understanding of a phenomenon. Socio-technical research approaches are helpful in guiding us when investigating these people-focused energy transitions[4], [5], and open up discussions so that the human side of the technological change can be explored [6].

Socio-technical and qualitative social approaches acknowledge people are actors in a network of influences that impact the way a technology is taken up. People's experiences and tacit knowledge are valued as data, whether it be about themselves, others they observe, their environments, or the systems they work in. Insights can be captured through discourse and engagement with people, and through observation of their interactions with the technology and the broader environment at hand [7].

Each person is assumed to have their own perspective and situational bias. Bias is seen as a ubiquitous human trait that does not lessen the value of discourse and insights captured from each person. Bias is factored in by capturing diverse voices to understand a situation [8]. Various perspectives are therefore sought in the research to support exploration of the different perspectives people may have about a situation [8]. This allows capture of as many angles as time allows for an issue.

The intent is to build a rich picture of perspectives from different viewpoints, from people in different (relevant) contexts. People are encouraged to present their range of views and effort is made by researchers to ensure people participating have space to speak their opinions. Critical feedback is sought on various aspects of the approach of, and the context of, the technology at hand. Critique can be anywhere from positive through to negative feedback. These critical insights are valued because they map barriers and opportunities for technologies and often

capture emerging insights not formally recorded anywhere else. Social acceptance or lack of acceptance can be assessed through these engagements and considerations for next steps of design and implementation of the technology at hand can be recorded and disseminated from what is learnt.

This is a trial of an emerging technology, that currently is being developed in a protected 'niche'.

Converge is a technical trial to test viability of a possible technical solution for society. This trial tested the early version of this solution. It is currently in development with further work needed to apply it at scale in Australia. Strategic niche management (SNM) research approaches are helpful in these instances [9][6]as they help conceptualise the position of a new technology or innovation as it is developed and tested. Niche innovation is seen to allow development of a technology without it greatly affecting what is described as a 'regime' or an existing incumbent system. The 'strategic niche' is the 'space' provided, by the permission of various organisations and related consumers to test and manage learning and development about the technology safely. The 'niche' space allows application of the new technology (to some extent) in practical (real) environments where viability of the technology can be tested at a small scale. SNM recognises that many ideas start at a small scale and need to develop before they can become mainstream. Designers and creators learn much at this stage that can be applied to improve the technology in application before it is scaled.

Converge technology has been developed in a strategic and protected niche space. SOE technology trials were funded and developed as part of an Australian Renewable Energy Agency (ARENA) trial and have been applied via two existing aggregators with 1001 of their household customers who have DER (this is not all their customers – it was not a blanket application). Converge SOE technology is not yet embedded into existing processes and is not yet fully developed commercially. During this trial, the embedding into processes was tested in the ACT, on particular parts of the network and with Evoenergy – the network operator - observing and checking the test application. Running an applied trial such as this one for Converge has allowed testing in a protected but practical and applied space, which in turn has provided further understanding of how this technology can be further developed and then maybe applied at scale in Australian systems.

SNM and sociotechnical theory are often used in conjunction to support research and assessment of new technologies being testing in niche situations. Alongside socio-technical approaches, SNM theory (also) acknowledges the importance of social perspectives and contexts and how they interact with new technologies and their evolutionary trajectories. The social technical approaches used here allowed us to capture and comprehend emerging evidence about how the SOE niche technology might weave in with and impact the incumbent energy and aggregation services systems via engagement with a variety of people looking at the technology from different perspectives.

Stakeholders of the energy system – intermediaries - will be involved in moving a technology from niche to scaled.

SNM, and other approaches such as actor network theory, social ecology and organisational psychology, have demonstrated how critical stakeholders are as actors in the technological regime or system. In theory, in relation to technology development, stakeholders involved in key

roles in the system are often contemporarily termed intermediaries, or innovation intermediaries[10], [11]. Intermediaries in this piece of research are human actors who have knowledge about or act in any relevant system that the new technology – SOEs - will have to interact with if scaled. The social research for this project uses the concepts of intermediaries as developed through transitions and innovation research, where intermediaries are seen as brokers and catalysts who can have a range of functions in any system or innovation niche (for example Kivimaa et al 2018 [12]). Our recognition of their importance and their influence on possible outcomes and the systems implemented to engage new technologies and also to monitor and manage their effects on end consumers, has led to us including a range of intermediary engagements in this qualitative work.

Key intermediaries in this instance are spread throughout the Australian energy landscape and include energy system employees in commercial and government positions, energy suppliers and retailers, energy system innovators, advocates for consumers, aggregation services companies and more. We aimed to capture a range of intermediaries and descriptions of the groups we spoke with are listed in the intermediary social science report [3]. Points covered and discussed in stakeholder engagements are listed in Appendix B.

A key intermediary in this instance are organisations offering aggregation services. These organisations may be running virtual power plants, be a traditional energy retailer who has expanded to managing DER, or an aggregation technology provider assisting other energy providers to manage DER. Aggregator roles are described later in the report.

Including energy consumers - both those experiencing the technology and those who are not yet - is always important.

Anyone effected by a technology being tested needs to be consulted whenever possible. Householders are key in any energy supply technology test. They are major energy consumers and producers, with their DER ownership at a significant level in Australia. Householders are also more than just a customer or a market participant. People use energy for needs as well as wants in their lives. Energy is a basic underlying public good resource that is supplied to ensure people thrive. Energy supply is not the end goal; speaking to people as householders allows us to consider energy as an end service. Energy consumers provide a different point of view to intermediaries (who often speak from a professional or a community level role) and can provide important evidence of the end effects of energy technologies.

Consumers directly involved in the case of Converge SOE tests are householders with DER who engage with the SOEs via aggregation services. As the intention is to find a broader and scalable capacity management solution, it is important then to understand energy consumers who could also - whether now or one day in the future - become involved with SOEs, as well as those who may one day decide not to be involved or may be excluded from involvement. All these consumers give us a picture of how things are and what they may become with this new technology. We sought an expansive view of potential effects on and potential actions of householders, asking about, for example, home installations related to the technology, underpinning values and motivators, reactions to SOEs, impressions of the importance or not of SOEs, and challenges in getting involved.

Householders are not the direct clients for SOE technology developers because the technology would be processed through companies involved in DER aggregation services. Currently householders may be affected in secondary ways by SOE solutions. For example, by having an agreement with an aggregator that factors in an SOE; or energy production and use management being affected by SOE function through their household DER assets. As this project has an eventual aspiration that SOEs could be applied at scale in Australia (even if SOEs end up slightly different from their current form while in testing) it is likely that people who are not directly involved with SOEs could also experience effects of their application.

Other operating envelopes do affect householders directly now, without aggregators as intermediaries. Fixed, or static, operating envelopes (FOEs), are applied to constrained networks now and can, for example, limit how much solar photovoltaic (PV) generation can be installed at each house (see Appendix C for explanation). Forms of dynamic operating envelopes are also being applied via networks (in areas in Queensland, South Australia and Western Australia) with direct energy use effects for households. Application of a DOE, for example, mean that householders may be allowed to install a larger photovoltaic system, but with the condition that the network can limit their solar exports when the network requires restriction.

Whether effects from these operating envelope technologies are ultimately positive or negative (or perceived as such) is important to understand from consumers, in particular how they are likely to be affected and if they would receive or accept DOEs and SOEs.

Points covered and discussed in householder engagements are listed in Appendix B.

We sought iterative and emergent understanding by layering up insights from different steps of fieldwork and capturing different perspectives over time.

This research was exploratory work about technology that is minimally understood socially and therefore we took an iterative, emergent approach to knowledge development. Researchers learn along the way through layers of research and investigation and an iterative research approach supports this process. We used research questions rather than a hypothesis as guide. Questions are especially useful when a phenomenon is complex, as is the case for energy transitions solutions and the DOE and SOE solution space. The technical innovations create unique social phenomenon and researchers need to layer their understanding of social and technical interactions as they progress to build a rich picture. Additionally, iterative emergent approaches allow for adjustments in the research trajectory as research progresses, as what is learnt along the way can alter the path of inquiry, to better meet overall objectives. This research approach aligns with the iterative approach that technology designers often need to use to progress their design through to technology readiness levels [13], [14].

2.2 Methods

This methods section describes various aspects of our methods, to ensure that readers can understand our approach, where useful. More detailed description here is necessary because approaches in research greatly affect the data collected; laying out our approach allows others to utilise what may be useful and to compare approaches. Some methods details including questions we used in workshops and interviews are also detailed in the appendices (Appendix B).

Multiple qualitative methods were used, with emphasis on one-on-one and group conversations and gathering qualitative data about phenomena relating back to SOEs. Insight was sought from a variety of stakeholders and householders to capture their diverse points of views to ensure a multi-perspective picture, 'triangulated' understanding [8], across the stages of trial. Multi-methods and multiple views captured, as indicated in the section above, assist us to understand phenomena from different perspectives, to map key intermediary actor positions, and mitigates perspective biases.

Insights were captured from 58 participants who were professional energy system stakeholders (intermediaries) and householder energy consumers. Insights were also captured from 13 SOE team members during two design discussions. We included stakeholders likely to know about operating envelopes or their effects on organisations, systems and/or communities and consumers. Stakeholders were from various locations. Some householders involved were part of the Converge trial and some were not. Householders involved had a range of experiences with home installed batteries, solar PV, inverter assets, and electric vehicles. Most household participants were current DER owners, with some with no DER. Householders in interviews were all battery owners and involved with an aggregator. Householders in the workshops included people with and without the distributed energy resources just listed above. All householders were from the ACT (Converge technology was being trialled there) and had the potential to be affected by future operating envelope strategies on electricity networks (they were all connected to mains electricity grids). Converge technology design and development team members joined in on two official focus group conversations and in regular shorter team meetings. Multiple organisations contributed to Converge and contributed insights for the social research.

We sought participants' understanding and insight to support their inclusion in decision-making about future investment in operating envelopes, involvement with grid integration and with SOEs in particular. Seeking diverse voices also helped us to step back from current industry assumptions to better understand what might affect acceptance/lack of acceptance and introduction of a new technology in the grid integration and operating envelopes landscape.

Key aspects of the social research included:

- Ethics was gained for the social research in mid 2022.
- Capturing 20 stakeholder points of views from 17 organisations, via 18 interviews – from late Sept 2022 to Early December 2022.
- Conducting 2 group reflections with 13 Converge technical design team members (12 people attended each one) - one was held 16th August 2022 and one on 28th February 2023.
- Providing methodologies (as a report) to ARENA with explanations of the approach, theories and methods planned for the social research in March 2022.
- Providing an initial report (interim report) to ARENA, about SOE and DOE technology, based on stakeholder interviews noted above in March 2023, with publication in May 2023 [3].
- Interviews with 11 battery owning householders who are customers of the companies that provided aggregation services in this project. Some of these households were taking

part in the Converge trial – these were conducted late November 2023 to mid-January 2024.

- Workshops with 25 energy consumers who were in the ACT. None of these people were participating in Converge trials. Three workshop events were held - on 26th November 2023, and the 12th and 14th December 2023.
- A workshop discussion with 14 stakeholders to report back in about the social research and trial outcomes. This group was invited if they had taken part in stakeholder interviews. Two stakeholders were new to the cohort as they were nominated to attend by stakeholders who had been directly invited. This was held on the 12th of February 2024.
- Regular project management team meetings with the Converge team, attended by social researchers from August 2022-March 2024.

Timing of the social research

The overall project timing and how the social research rolled out in context of the overall trial is presented in Figure 1. The trial began after contract signing in November 2021 with the software build and recruitment continuing through 2022 into 2023. Trials of the SOE platform, first as stand-alone tests and then via aggregators using household batteries, were conducted in the last half of 2023. Social science recruitment and data collection with participants occurred in periods of time from 2022 until early 2024.

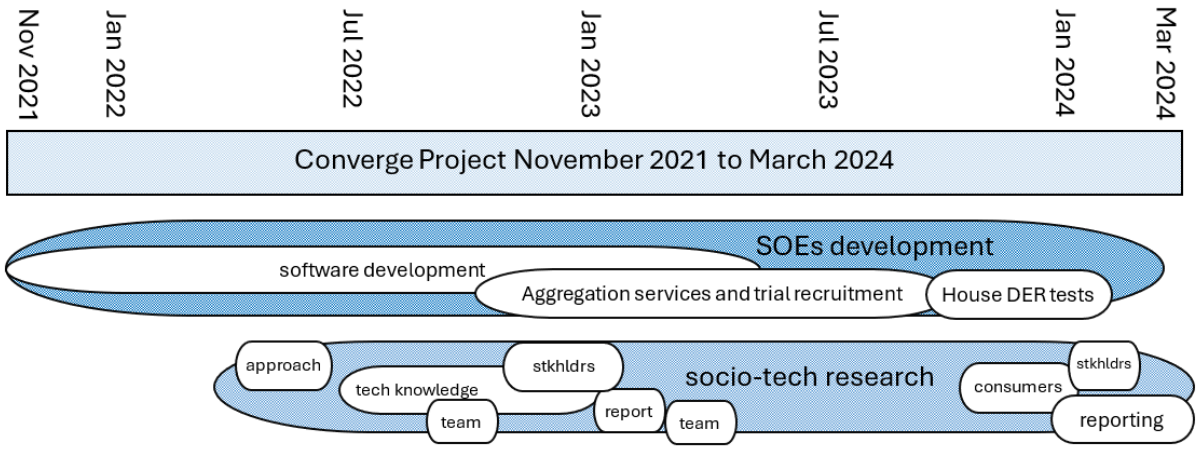

Figure 1 Social science in the project timeline

The social research was timed so that we gradually developed a rich picture of SOEs via qualitative input from different parties. The stakeholder participants were engaged relatively early in the social research process to capture their thoughts as SOEs were being designed. Stakeholders were also engaged at the end of the research period so we could discuss with them insights that had emerged throughout the social research. Householder consultations were timed so that battery owning household participants involved in the trial could be included in interviews after there had been some trial activity on their batteries. Project delays meant that the technical trials with householders were later than first anticipated. Additionally, householder consultations were left until later in the process so that social researchers could better

communicate what SOEs are. Definitional development of SOEs was underway through the project, as is common for developing technologies. We spoke with householders when we had a clear idea of most of the features and impacts of SOEs. Observation of SOE design processes, and discussions with team members about SOE design and development occurred throughout the social research.

Dates of interviews and workshops are listed in further detail alongside further participation description in Table 1, in the section below.

Participation

Descriptions of participant groups, recruitment avenues and the ways various people participated in this research are listed below in Table 1. Seeking diverse voices allowed us to capture different perspectives and to step back from the main industry assumptions to uncover factors, including issues for people, that would influence implementation and acceptance of dynamic and shaped operating envelopes. We used interviews to capture more direct experience or to have an in-depth conversation about specifics, and group discussions to capture collective thinking about the notion of DOEs and SOEs more broadly.

The findings of this research are unlikely to be directly useful to end consumers of energy (in this instance householders). While they were not the direct clients for SOEs, both DOEs and SOEs will directly influence consumers in their homes when SOEs (and DOEs) are in use. Including householders in this work ensured consumers' lived experiences of energy use and DER experiences were captured, including as the SOEs interacted with their consumer energy assets. Their participation allowed us to articulate their values, needs, and desires in terms of the technology and the application context.

Table 1 Social science research events

Cohort	Participant description	How recruited and selection process	Participation
Converge development team members	Researchers and innovators from energy industry and ANU who were involved in developing DOEs and then SOEs in Converge.	Known to social researchers already. Directly invited via email.	Regular team meetings throughout the project, one online focus group 16.08.22 with 12 (the majority) of the team, and one face to face focus group 28.02.23 with 12 (the majority) of the team. 13 team members took part in the team focus group discussions, excluding the social researcher who ran them.
Intermediaries – professional stakeholders	Key stakeholders who have energy system expertise and work in the DOE/SOE development landscape or in related areas. Diversity of backgrounds and organisations sought and recruited, including people with understanding of operating envelopes, electricity systems and consumers.	Recruited direct via email through professional networks of the Converge team, as seeking specific knowledge related to energy futures, and those involved with relevant energy issues (related to DOEs and SOEs). Some participant suggestions came from those contacted. Two new participants involved in 2024 workshop where volunteered by original stakeholder participants. Recruited from DNSPs, aggregators	1 round of interviews with 20 people from 17 organisations in 18 interviews. Invited 33 people in late 2022, so a 60% response to invitations. 1 workshop with 14 people (had a goal of min 8 people), 12.02.24. Invited all people who attend the first round of interviews – 20 people. Two further people were recommended. Overall, 63% of invitees attended.

Cohort	Participant description	How recruited and selection process	Participation
		and aggregation software and technology services, regulators, observer and advocacy organisations.	
Battery-owning householders - some taking part in Converge trial	Battery-owning householders in the ACT who are customers of one of the 2 aggregators involved in the trial. Some of these households were taking part in the Converge trial and others were not. Majority were longer term battery owners (a long-time past installation), with longer term involvement with an aggregation service (involved in SOE tests). Initial learning related to new batteries was in their past. This length of familiarity with their battery is useful as most other energy transformation trials have participants new to batteries and other DER technology. DOE and SOE solutions were still mostly new knowledge for these participants.	Participants were invited to take part via aggregators. This was after people had been recruited to the Trial. So, the recruitment of 1001 customers occurred before the social research recruitment for conversations. One aggregation service provided invites to over 200 contacts via emails with most being non-trial participants. Around 16 were invited who were participants. The other provided an unknown number of emails (it was a small number)and we received 3 responses. Aggregator customers invited some people taking part with SOE trials and those not. Because of the scale of the trial, participants were recruited from across the ACT. Workshop recruitment targeted participants who were involved with the trials. This allowed interviews with people who decided to take part in the trial and were involved in SOE tests and also with people who had decided not to take part.	Interviews of up to one hour each online. 10 interviews, with 12 people, and one person volunteering an email contribution (providing us permission to use it). 4/12 participants from aggregators had their batteries involved with SOE trials. The other 8 interviewed had considered taking part. Most participants are from one aggregation service, and this is related to that particular aggregator's more extensive engagement with us during recruitment. Participants were sent a $50 grocery voucher if they provided their address (only one person did not).
Diverse household energy users	We recruited a mix of people of people to the householder workshop consultations. These people were not involved with the trial and included people with a mix of DER experiences – some with one or more DER assets and some with none. All the participants for workshops live in the Australian Capital Territory (ACT). These people took part in workshops in later 2023 and early 2024.	Recruitment for these participants was via Evoenergy, who sent out a general email to around 200 people and then ran a Facebook advertisement. The Facebook advertisement was the most successful.	Workshops – 3 workshops were held, with 25 participants overall. The workshops were up to 1.5 hours long. The 1st workshop was in person on the 26.11.23 at the ANU Acton Campus in Canberra and included 16 participants, the 2nd was online on 12.12.24 and included 8 people. The final workshop was on the 14.12.24 and had one participant who could not make the other workshops. Participants for the householder workshop were given a $50 grocery voucher.

Engagement and insights sought from participants

Interviews and group discussions gathered stakeholder and consumer perceptions of the shaped operating envelope technology and other related information. We summarise topics we pursued in the research with participants here briefly and provide further detail in Appendix B.

We sought to develop an informed perspective of stakeholder and consumer responses, interrogated prevailing assumptions, mapped the current context affecting operating envelope evolutions, and captured issues and factors for people in both professional and consumption/CER prosumer positions that would influence implementation and acceptance.

In stakeholder (intermediaries) interviews and then in the workshop we sought to understand a range of topics including:

- Thoughts on operating envelopes as solutions,
- Intermediary activity in innovation relating to operating envelopes,
- Current key contextual features/factors that influence DOEs and key intermediaries who will be involved with DOE and SOE development and application,
- DOEs, their development and application,
- SOEs as a new evolution of operating envelopes,
- Industry related to operating envelope evolutions,
- Key consumer considerations in their minds, and
- Responses to the SOE trial outcomes.

In consumer interviews and workshops, we sought to understand a range of topics including:

- Direct responses to experiences with the SOE trials (including what they noticed and their decisions to get involved or not),
- Their energy experiences at home, including some with DER/CER and some without,
- Experiences and opinions about DER/CER grid integration,
- Related experiences and opinions about the changing grid and the solutions being applied,
- Principles they think need to be in place for grid integration to work and,
- Thoughts on related electrification from their perspectives.

As operating envelopes are not commonly understood concepts in society currently, and SOEs were unknown except in our team, information was shared on operating envelope evolution, DOE and SOE technologies, and related background at each discussion we undertook. SOEs were explained more technically to stakeholders and in more ‘accessible’ language to consumers, to ensure that all people in the consumer group would understand what we were sharing (we assumed there would be few consumers attending that were well informed about power systems specifics and the power innovations landscape). Explanations provided to consumers are described further in Appendix C.

DOEs were an important part of discussions, particularly in stakeholder interviews, because they have been relatively broadly discussed in intermediary DER energy communities and they are also currently being implemented in various forms around Australia. DOE discussion therefore provided a useful base in interview discussions and supported discussion about SOEs and

evolving operating envelopes in general. SOE concepts were less familiar to most interviewees and therefore discussions about SOEs were more speculative.

SOE-design related stakeholder insights from interviews were deidentified and shared with the SOE design team during team focus groups for discussion. Further participant insights (deidentified) were also shared gradually at team meetings as opportunities arose.

Data processing and analysis

This section notes the key data collection and analysis procedures used. Stakeholder interviews and team focus groups were recorded and transcribed using auto text identification. Recordings were listened through while checking auto coding to ensure transcripts followed the discussions closely. Household interviews and workshops and the final stakeholder workshop were professionally transcribed. Transcriptions were coded using qualitative data analysis software (NVIVO in this instance). They were coded for content, meaning and implications. Any comment made by a person contains levels of meaning and can hold information that is useful as a content descriptor (about direct description of context or opinions for example), to indicate meaning, or because it has potential implications and assumptions underlying it. The social researchers also had multiple sessions to talk through and explore the codes that were emerging and to identify what to prioritise of the emerging themes. Prioritising codes included factoring in the aims of the social research, what had emerged as new knowledge, and the likely audience for the report, among other factors. Key codes were also selected using a background of understanding that researchers have developed through their history of research on energy systems.

In this research we deidentify analysis when reporting findings. We use codes or pseudonyms or generic descriptions of the roles the participants hold as is relevant when referring to their comments and quoting them. Where there is a possibility that quotes and identifiers could still identify a person, role titles from quotes are removed. Interview participants were also emailed near to complete draft versions of the main report (at the same time it was sent to ARENA for review). This allowed participants to check the use of quotes and the reporting of findings. Participants did not request any adjustments to quotes or the report when it was sent to them for review.

Researcher(s) position (s)

It is useful in social research to state the position of the social researchers, so readers are aware of how they interact with the wider project. In this instance, the social research is being conducted from inside the Project Converge team. Dr Hedda Ransan-Cooper planned the social research and approach (methods) in initial stages. Dr Phillipa Watson conducted fieldwork in 2022. Watson was joined by a broader team – Laura Jones, Brenda Martin and Sarah Wilson – as researchers in late 2023 and 2024 for the last stages of social research, analysis and reporting. All social researchers were employed at ANU through the same ARENA grant the designers and developers of the SOE solution were employed through. Social researchers often seek technical context understanding as they research. In this case early technical context support was provided by Andrew Fraser who was ANU project lead for Converge until mid-2023. Laura Jones became technical project lead at ANU in mid-2023 and also took part in the social research and provided technical context to researchers during her time in the project.

All researchers and project leads noted above were part of a broader transdisciplinary socio-technical research group that has worked on multiple other energy transition projects at ANU. This background in energy transition research (and in DER orchestration and coordination as part of that) informed the research conducted.

3. Electricity futures and network capacity - key influences in the context

This section relates key electricity and network contexts that created the problem and opportunity space for SOEs and Project Converge. Key influences that underpinned decisions to explore SOEs, and then led to funding by ARENA were:

- Increased uptake of generating and energy consuming devices such as solar photovoltaics (PV), electric vehicles (EVs), and batteries (sitting at homes and premised behind the meter);
- Concerns about current energy network capacity related to increased use of electricity and electrification and the significant effects of PVs;
- Widespread expectations that people are going to increasingly elect to participate in two-way CER and DER sets ups with electricity systems and in Virtual Power Plants (with their CER); and
- An innovation landscape where various aspects of CER grid integration were being explored when SOEs were devised.

Substantial levels of connected PV around Australia, increasing numbers of EVs requiring charging are contributing to increased congestion in the electricity network. Congestion occurs when there are too many simultaneous (coinciding) demands for electricity, or exports from DER (especially PV) to the network. For example, solar PV systems generating on a sunny day are now in many jurisdictions generating a high proportion of the power in the system at that time. This coincident PV energy, while helpful for decarbonising the electricity system, causes problems for power flows because exporting excess energy onto a network at the same time can push the network beyond the upper threshold (and go outside the safe capacity of the network). Batteries also, while often seen as a useful device that can assist to solve coincident network problems can also cause their own types of peak demand problems. For example, peak demand or generation can occur when large numbers of aggregated batteries all respond to events like high or low market prices.

Physical network overload often manifests as excess heat in network assets or power quality issues (such as high or low voltage). Heat causes asset failure or overhead distribution lines to exceed their design temperature leading to excessive sag. Because capacity is related to temperature, network capacity will vary with weather. For example, on a hot day the network has less capacity. Power quality issues can cause damage or mis-operation of consumer devices.

Congestion and flow management in distribution networks is not a new phenomenon. Networks continuously plan for changing energy demand, as can be seen in annual planning reports [15], [16]. These new pressures on congestion are somewhat different and require new management strategies. There are concerns that the amount of network that is needed to accommodate the increasing demands from DER could be too expensive [17]. The cost of network needed to allow full export of coincident PV, for example, is looking to be high. In the instances of PV export capacity, in the current system, these enhancements to the network would be paid for by all, including people without PV and could exacerbate inequity [18]. There is a desire to avoid building more poles and wires due to the significant expense that entails.

There are a range of possible solutions that can help to solve the current capacity challenges. Solutions that manage network capacity through means other than expanding the network are called “non network solutions”. A range on non-network enhancement solutions are used both in Australia and overseas, with further solutions in development. Some examples are:

- Encouraging people to change when they consume energy using pricing [19];
- Direct control of load by DNSPs, for example in Queensland Audio Frequency Load Control (AFLC) approaches have been used to turn off hot water systems at peak times since the 1950s [20]
- Direct contracts to alter demand are commoditised and traded on markets in some parts of the world [21], and
- Encouragement of energy efficiency in supply and use, as in the Oregon Energy Trust [22].

SOEs, and their progenitor technology, Dynamic Operating Envelopes (DOEs) are a type of ‘non-network’ solution applied by DNSPs to resolve network constraints. Dynamic operating envelopes manage capacity by placing various types of limits on consumption and generation ahead of time. DOEs and SOEs seek to manage constraint issues by providing close-to real-time guardrails or operating envelopes, which protect the network from exceeding upper and lower bounds. Close-to real-time operating envelopes work through networks publishing a view of their technical limits electronically and in close-to real-time to consumer devices.

DOEs are currently operational in parts of Australia, while SOEs have been tested in this trial. DOEs are implemented to manage generation via connection agreements in South Australia [23] and Queensland [24], with other states also considering their uptake. They facilitate networks responding to close-to real-time generation limits sent by networks and are being applied as conditions of connection for new PVs in South Australia.

SOEs are an evolution of DOEs, enabled by an expectation that many people may want to participate in virtually orchestrated two-way energy management with networks via aggregation services, and mostly through Virtual Power Plant (VPP) approaches. VPPs are electronically managed systems that can work to coordinate energy sharing from hundreds to thousands of small, distributed energy devices, such as home battery systems. VPPs are operated by organisations who provide aggregation and orchestration services – often through an energy retailer or a separate company that provides aggregation services [25]. These aggregators work as intermediaries selling energy ‘services’ to energy markets (for the sorts of services an aggregation service might provide, please see [26], [27]).

Virtual aggregation and coordination of many distributed energy devices is a relatively new service and approach for the Australian electricity grid, having been trialled in applied settings from the 2010s in Australia [28], [29], [30]. Virtual coordination developed in Australia as solar export pressure grew, peak demands were increasing, and battery technology became enabling of two-way exchange in a more sophisticated way. From the point of view of the distribution network, virtual coordination can be a risk and an opportunity. Virtual coordination could increase coincidence of generation and consumption patterns toward market signals but also has promise for DNSPs to use these same coordination capabilities to better manage their networks [31]. Aspects of this coordination capability are being tested in Converge.

Aggregations services are maturing. Early aggregation services organisations such as Reposit Power have been extant for 10 years in Australia now [32]. This means that distributed energy owners who are participants in VPPs can have had a relationship with an aggregation service for long enough for them to be comfortable with them and be long term customers. This movement and evolution of aggregation services has allowed the growth of expectations about what these companies can do and enable. In the instance of SOEs, aggregation services were seen by designers to have the potential to enable a new kind of participation in DOEs as well as enabling market participation. Thus, one of the main differences between SOEs and DOEs is that SOEs include an aggregator formally in the algorithm. SOEs and how they work are further described below in Section 4.

An innovation landscape - to engage with DER/CER and to better apply operating envelopes - has emerged due to challenges and opportunities in the electricity network noted above. There are a range of organisations who influence the solutions tested and are interested in the outcomes of innovation in these spaces. That there is an innovation environment, with stakeholders (intermediaries) prioritising support for particular applied solutions to be tested through application in niche testing spaces, indicates the level of interest and focus in this solution space and indicates the potential influence of relevant solutions. The Converge solution space has been influenced by this innovation context. Some notable influences are:

- ARENA assists with the development of projects proposed as solutions and did so in the case of operating envelopes, including DOEs in Project Evolve [37] and SOEs with Project Converge. They are an important monitor and intermediary in the electricity innovation space in Australia due to their activity and funding in the areas.
- There was development and rollout of other innovation projects that are testing other solutions that could either sit alongside or overlap with SOEs as a solution. The knowledge that ARENA and the innovation community had of the other projects underway or being designed when Converge was being developed, affected what was trialled in Converge (and therefore what SOEs became). The main projects also testing DER and capacity-related constraints around that same time are Project Edge [33] , Project Edith [34] and Symphony [29]. SOE testing was designed to explore a space alongside, but not completely overlap with, other tests and trials.
- DNSPs are dealing with what are looking to be network capacity issues and have therefore been deeply involved in solutions development and testing. Key personnel of Evoenergy, for example, were allocated and have been involved in both Evolve and Converge projects because of the need to have solutions in this space.
- Aggregation services are currently available to engage in innovation processes as they identify ways their business can grow aggregation services and/or VPPs.
- There are expectations in the innovation space that pressures described will increase and that more consumers are likely to want to own DER/CER and participate with virtual aggregation services and energy markets in the future.
- That some key systems cannot be changed for niche projects. Because this was a trial, changing certain things such as participant retail contracts, participation in energy markets, and connection agreements could not be undertaken as part of the project. This meant that certain parts of SOEs (such as interaction with market participation) could not be tested to the extent that was hoped. The longer-term operational model has therefore not been fully decided.

The above descriptions and explanations indicate how operating envelopes are a solution designed for network supply challenges and have been designed in a particular context, with particular influences. They have been designed in an environment where pressures are building and there is an innovation landscape prepared to test solutions. This has implications for the solution paths tested and taken. Householders are not involved heavily in the innovation landscape and often do not have a direct say in what solution paths are chosen. In this instance we have been provided a space during design and development to begin to test assumptions and solution paths with householders through this social research.

4. SOEs – what they do and how they are applied

This section builds on the previous section's information about of the energy context in which SOEs have been developed by describing SOEs as a technology and in application. DOEs are also further described here. The descriptions provided here build on information provided in earlier project Converge reports and in the final technical report [2], [3], [35].

This section: first provides a technical description of SOEs; then describes implementation contexts for SOEs, including the role of intermediaries.

4.1 What SOEs do

As noted in section 3 above, SOEs were envisaged as growing and evolving from DOEs. SOEs effectively developed from the integration of dynamic, price-based optimisation as explored in a number of DER optimization trials, with the original project's idea being tested in:

- the CONSORT Bruny Island battery trial 2016-2018 [36]
- the Optimal DER Scheduling for Frequency Stability project on frequency 2020-2022 [31],
- The South Australian Power Networks flexible exports trial, and
- The DOE approaches explored in the Evolve project 2019 to 2023 [37].

The main aims of the Converge project was to explicitly add consideration of how aggregators were intending to bid to DOE approaches. This was said to enable DNSPs to *shape* aggregator market bids. Given aggregators were also expected to know more about how consumers were using their DER and future flexibility capability, including aggregators in the SOE approach also promised to enable SOEs to take better note of consumer intention than DOEs.

As the SOEs add to a DOE process, some explanation of DOEs is set out here as a basis to explain SOEs. DOEs are a way of allocating network capacity. They have been used in Australia now to allocate capacity among DER generators such as rooftop PV [38]. DOEs are calculated in real time using a process shown in Figure 2. DOEs involve networks assessing their capacity to supply and accept electricity, then identifying how they will apportion energy supply among consumers, and finally allocating DER access to energy exports (sharing energy from a sight back to the grid). Consumers are then responsible for operating their DER within the capacity limits as set. SOEs primarily act to enhance detail and decision making at the capacity allocation stage, when operating envelopes are being dynamically assessed in the DOE process. This step is also shown in Figure 2.

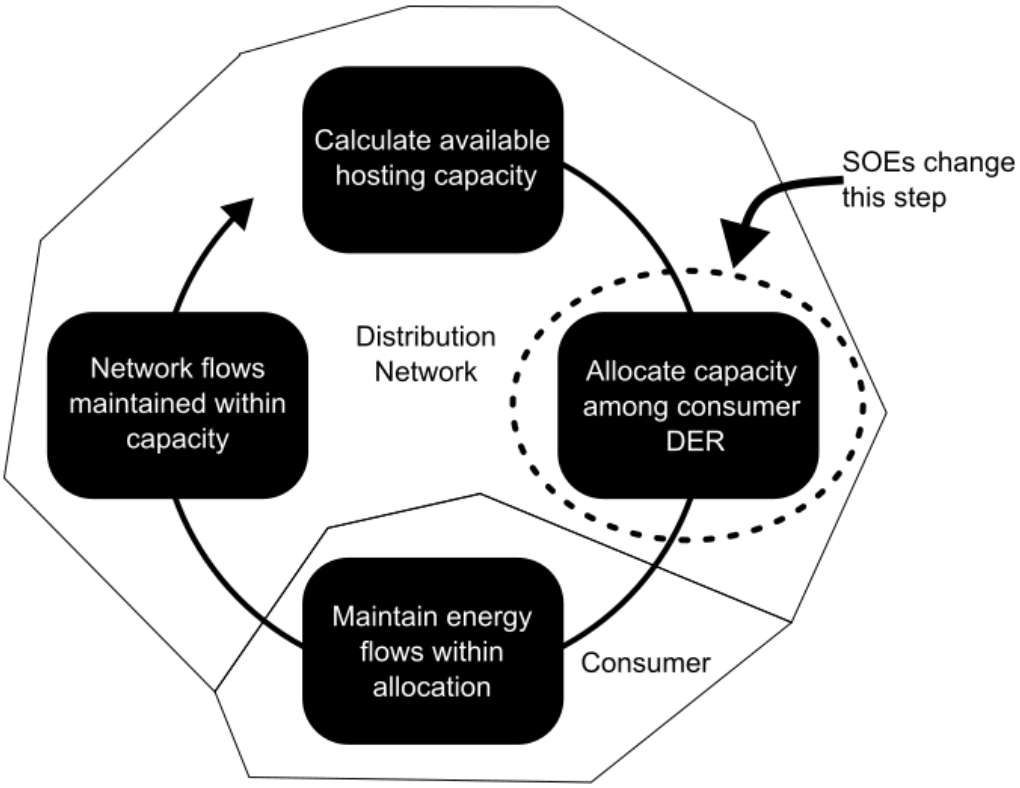

Figure 2 DOE lifecycle and SOE changes (adapted from [1]

The capacity allocation approach used for SOEs (in the Converge trial) differs from that used in DOEs, as it adds multiple extra capacity assessment steps. These steps are designed to open up the capacity allocation process to aggregation services (aggregators). Extra capacity allocation assessment is undertaken in SOEs so that operating envelopes can be better allocated according to available need and available DER/CER support. Extra assessment of capacity and better ability to respond could also make the design more efficient than DOEs alone.

Underpinning SOEs is a clear expectation that aggregators would be undertaking dynamic price-based optimisation with consumer DER. SOEs can integrate with this optimisation and be involved in DOEs. Aggregators are included as the key intermediary in SOEs decision making for a number of reasons. In particular:

- Aggregators need to understand consumer intentions to bid capacity into the market, and inclusion of consumer intentions in capacity allocation is anticipated as enabling networks do a better job of allocation of electricity.
- Aggregators have been growing their base of DER/CER connections over time. These connections provide more detailed understanding of energy demands and times when DER/CER can provide energy and energy services. Therefore, these connections allow an opportunity to better understand - through SOEs - what electricity flows can be altered and how.
- There is evidence that aggregated DER controlled by VPPs could cause increasing network congestion [39], and through engagement with aggregators SOEs can assist to solve this potential risk.

- Aggregators have a commercial relationship with their customers therefore may have a better understanding of customer values and expectations around capacity management.

The SOEs approach therefore is to gain a better view of the intentions and needs of customers by including aggregators as their agents, and then reporting this back to DOE engines. SOEs make more detailed capacity decisions by understanding what is happening with consumer batteries and through considering the value of consumers sharing energy with the energy market and network. This understanding is built with two pieces of information: a request for capacity, and an offer for flexibility (that is consumers being more flexible in their energy use and exports to the grid). Figure 3 shows SOE related aggregator activities, which involve aggregation as a technical capacity, and factoring in consumer expectations and market prices into capacity requests and flexibility offers, for the SOE engine.

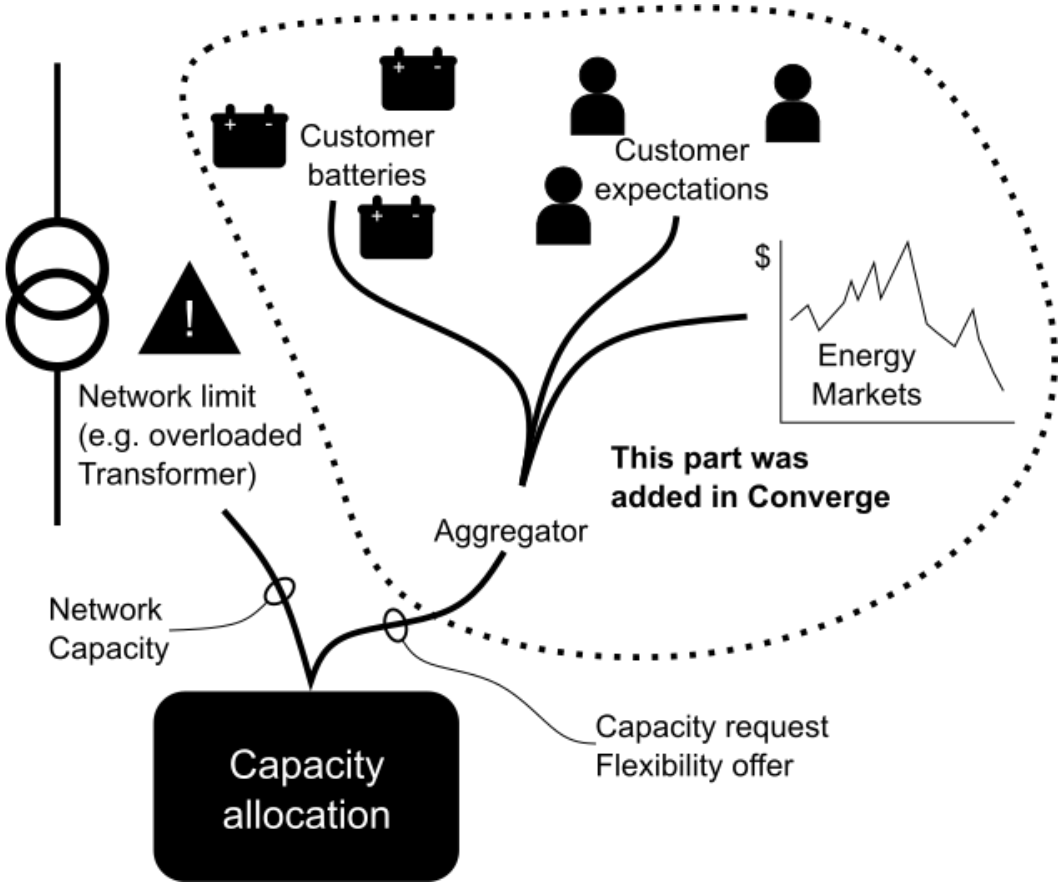

Figure 3 The inclusion of aggregators in capacity allocation.

In the SOE approach, aggregators feed two data points into the capacity allocation:

- A view of the energy exchange intentions of the customer (called “uncontrolled consumption/production” in the technical design [2]), and
- A view of the ability of the customer to alter their consumption and associated price (called “capacity contribution to market and network support bid band in the technical design [2]).

With information about both energy exchange potential and the ability of a consumer battery to contribute, networks can overlay dynamically assessed network capacity particulars and determine what actions are useful and/or could be accommodated. This process is called "shaping" and leads to the "S" in SOEs. Figure 7 shows how aggregators are integrated into the capacity allocation process. First, it shows how aggregators request capacity from and offer flexibility to DNSPs in step 1. Then it shows how DNSPs "shape" the capacity requests using the flexibility offers to respond to aggregators within the achievable capacity range, while taking into account their network capacity in Step 2.

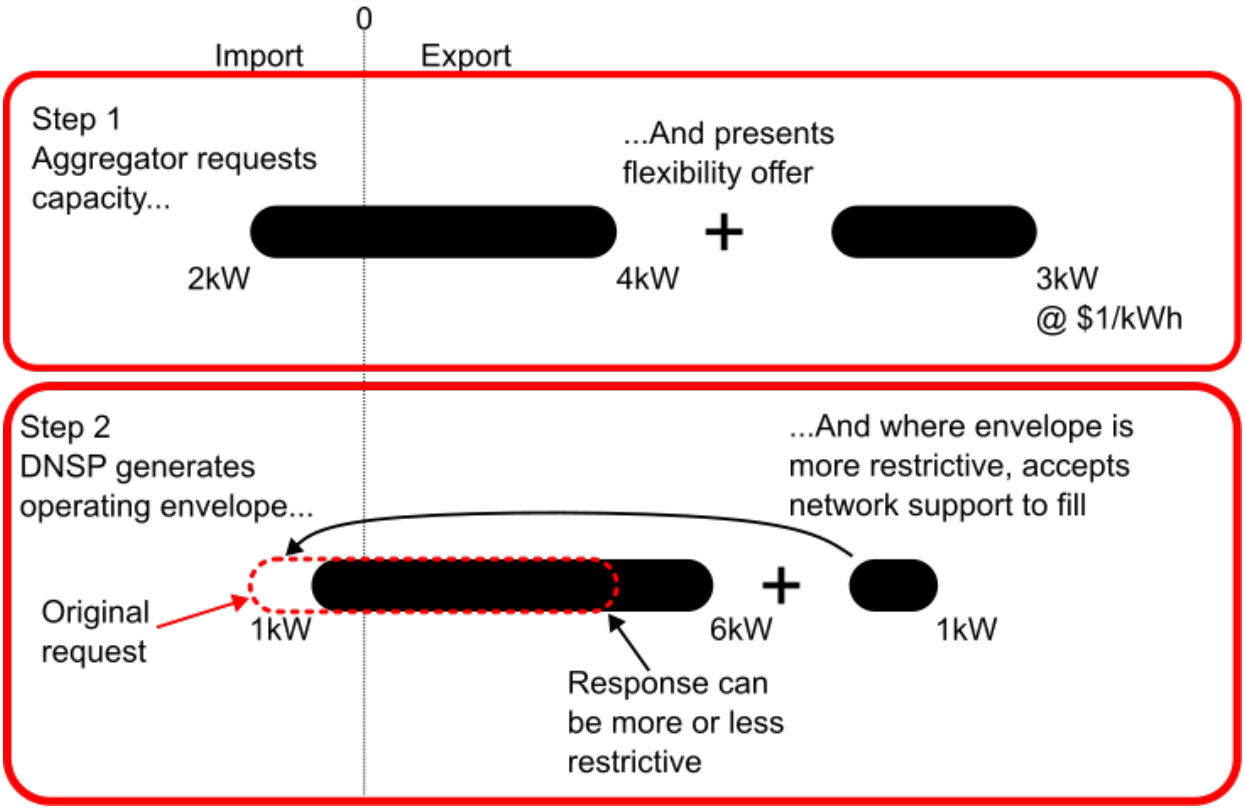

Figure 4 Capacity allocation

4.2 Applying SOEs

Aspects of how SOEs were applied and the outcomes of this are useful to describe in relation to later findings in this report. SOEs, alongside DOEs, are conceived as being part of the suite of technologies and approaches contributing solutions that support a more dynamically managed and flexible network from the network point of view [2], [37], [39], [40]. As previously noted, impetus to design and test SOEs came from distribution networks needing to advance the way they manage electricity network capacity, so they can delay large network upgrades as long as possible [3].

SOEs in this project were a niche solution tested in a protected, off market technical tests. This was the protected niche that Strategic Niche Management theory describes. Therefore, SOEs are in early testing and further design and development will be needed as they scale.

The Converge trial had 1001 consumer participants. Participants were already customers of one of the two participating aggregators in the trial. Technical testing occurred in the final quarter of 2023. There were three technical trials:

- Trial 1 tested SOEs ability to manage distribution network voltages,
- Trial 2 tested SOEs ability to manage distribution network power flows, and
- Trial 3 tested SOEs ability to manage voltage and power flows when there is a high concentration of DER (solar and batteries).

Through these tests there were 8,599 network support "events" (or requests to alter generation or consumption). These totalled 5.1 MWh altered consumption, or generation, over this period.

SOEs, unlike DOEs, have been designed to include aggregators in the capacity allocation process. The aggregator has several explicit roles in the SOE algorithm:

- Understanding and communicating consumer intentions and values to the algorithm,
- Forecasting future consumption patterns and communicating to the SOE engine,
- Altering consumer device behaviour in response to capacity allocations created by the SOE engine, and
- Participating in energy markets on behalf of consumers.

There is an expectation then with this design that the aggregator is a representative of the consumer in all ways. This allows the grid side of the SOE engine to focus more on the energy system needs.

The SOEs in Converge trials worked as part of already existing battery aggregation platforms. These platforms automate day-to-day operation of batteries on behalf of customers. Part of this automation is to propose flexibility capability to other energy market participants (such as DNSPs) where it is financially beneficial to the customer.

DOEs are being implemented in some jurisdictions today as a condition of connection of solar systems to the grid [38]. This means that there is an expectation that PV owners will procure appropriate technology, form the necessary relationships, and manage their DER in a way that results in them complying with the DOE as set by networks. As this is implemented through connection agreements there is no direct underpinning financial arrangement, other than the ability to install a larger PV system.

The Converge trial did not involve any change to connection agreements. Instead, SOEs were implemented through contracts with the two participating aggregators. This led to significantly different value propositions between each aggregator and the DOE approach used elsewhere. The differences in the value proposition between the two participating aggregators and the South Australian DOE approach is described in Table 2.

Table 2 Comparison of DOEs and the two SOE financial propositions.

Aggregator/approach	Description
South Australian Power Networks / Dynamic operating envelopes	Compliance with dynamic operating envelope is a condition of connection of a PV system larger than 1.5 kW to the grid. There is no ongoing payment to consumers for participation.
Aggregator 1 / Shaped operating envelopes	Where a participant's behaviour is changed, they are paid a fixed amount per kilowatt-hour of behaviour change.
Aggregator 2 / Shaped operating envelopes	Participants were paid $200 for trial participation invariant with how much actual response was requested.

Examples of how fixed (or static), dynamic and shaped operating envelopes could be applied were presented to participants. A summary of the explanations, outlined in Appendix C, provides readers with some examples. These explanations may be useful to people unfamiliar with SOEs. At this stage it is unclear how SOEs will be applied in the future, if they are used at scale in society. For example, it is unclear whether they will become a requirement to connect DER (or DER of certain types) to the grid, or whether they will remain implemented through network support contracts. We explore SOE application further by examining its features in the findings and discussion sections of this report.

5. Findings - Insights for SOE and grid integration development

This section reports findings of the social research for Converge. Findings have been compiled through a series of interviews, group discussions, contextual observations with stakeholders (from trial, innovation and energy DOE related environments); householders (with and without DER, those who took part in the SOE trials and those who did not); and, the SOE design team. Methods used and participant particulars are detailed in Section 2.2 of this report.

In this section we relate insights about householder and stakeholder responses to SOEs, to assist with future development of this technology and other operating and grid integrated technologies and solutions. We relay insights for SOE development generated from participant opinions about the SOE technology and participant experiences in the Converge trial; then, outline perspectives on intermediaries in SOE implementation and scaling; and, finally provide overarching findings about CER integration with the grid more broadly. CER integration is pertinent as a highly CER integrated grid is a key assumption underpinning SOE development, and indeed, many other current energy innovations that deal with DER and CER.

It is important to note that stakeholders and householders have different relationships with the application of SOEs and SOEs as a product. Stakeholders may, for example, apply SOEs in the future as an aggregation service or retailer, or regulate the use of them. Householders may or may not have a direct relationship with SOEs as a feature or a product. As the technical report outlines, SOEs are currently designed to be applied through aggregation services. The SOE feature or product therefore may actually be within an aggregations service's overall aggregation product. And, if so, the relationship with the aggregation service and the overall product may cast specific features of the aggregation decision making into the shadow.

Despite lack of clarity about what the SOE product might look like to consumers, it was recognised that consumers consultations were needed. The SOE design team discussed this at one of the team focus groups and one member explained:

> ...customers pay for networks, and I believe to operate in an ethical way, we do need to involve them in the decisions that we make that affect them in some way. (Converge team 16.8.22)

What people were responding to in discussion with us is important to note here as well. For both householder and stakeholder engagements, we had to ensure they had a reasonable knowledge of operating envelopes in general, and DOEs and SOEs in particular, before we could discuss their reactions. When we spoke with householders, they had mostly not been exposed to SOE concepts. Even those with aggregators in the trial were new to SOEs and had not necessarily paid SOEs much any attention yet. We provided householders with an overview of current energy system challenges, followed by a summary of the differing approaches through which fixed, dynamic and shaped operating envelopes facilitate the integration of consumer energy resources into the grid (see methods in section 2.2 and Appendices B and C). Due to the short amount of time we had with householders, we could only present a limited amount of detail about these complicated technologies. This meant householders were having to catch

onto these concepts and respond quickly. Stakeholders were provided with definitions and descriptions of DOEs and SOEs in interviews as required, and were provided with information on emerging householder analysis and technical SOE trial findings in the stakeholder workshop. Stakeholders were more familiar than householders with energy transitions, and operating envelopes. Some stakeholders were also very familiar with DOEs. As an emerging technology, SOEs are not yet fully defined and are likely to evolve further as they are implemented and scaled. That we were having to evolve our own explanations as we learnt more meant that our descriptions also developed over time, meaning later interviews and workshop included better explanations.

5.1 Insights for SOE development

This section reports insights directly relevant to SOEs and their future development. It relates perspectives on SOEs and on trial participation. All householders and stakeholders involved in interviews and group discussions provided indications about what they thought of SOEs. Some were more confident in providing critiques than others. In what follows we relate householder and stakeholder feedback. Overall stakeholder assessment of SOEs was already recorded in the interim social report for this project (which relays feedback from stakeholder interviews undertaken in late 2022 and early 2023) and this report covers different insights, with a focus on householder perspectives [3].

Responses to the idea of SOEs is related here to provide a general understanding of the responses participants gave when they were informed about SOEs. Perspectives shared on operating envelopes and SOEs identify the place SOEs might have in future operating management solutions and potential acceptance or lack of it. Overall responses offer useful insights into perceived positives and negatives of SOEs, and what factors would influence householder decisions to participate in an operating envelope system using SOEs alongside DOEs.

There was broad agreement from both stakeholders and householders that what SOEs were solving for was worthwhile, but with concerns and caveats. **Householders highlighted considerations** related to alignment with values, complexity and related communication needs as a challenge, and social fairness and equity as considerations related to participation with SOEs (and also more broadly for CER grid integration as well). There are particularities around these points that matter. For instance, it is not currently clear exactly how DER owners' perspectives or interests will realistically influence the operation of an SOE. Our research indicates that householders are likely to conceptualise having their preferences incorporated into SOEs much more broadly than industry does, thus providing a fertile ground for misunderstanding, disappointment and distrust if not carefully, and pre-emptively, addressed.

Stakeholders' overall views, like householders, were **broadly supportive** of the features that SOEs sought to support. Specifically, they appreciated that SOEs could provide better understanding of the value of available capacity, what was going on with consumer energy sharing assets, and that more parties (actors) were considered. Whether or not stakeholders would use SOEs in the form it was being trialled was not clear, partly because they, like householders, felt unable to fully assess the SOE product in full until they had experience of it in use, or until SOEs were further

specified. Stakeholders in the final workshop (12.02.24), for example, commented that what SOEs were optimising for mattered, and that allocation of capacity and allocation via SOEs also needed further consideration.

> I like the greater focus on consumer preferences in allocating capacity, but not clear how proactive the customer preferences expressed through the market mechanism are. How well will aggregators represent their customers' interests? (stakeholder workshop 11.2.24)

So conceivably the technical report being released in parallel with this final report will be useful for stakeholders as they asses the value of SOEs, with SOE features packaged the way they are applied in this project.

Values discussed by **householders** came across as clearly **affecting whether they could imagine taking part or not.** Some householders were supportive of the **broad value propositions** SOEs offer over and above DOEs. In particular, they supported the propositions to incorporate DER 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.

Related to solar wastage, a stakeholder explained that there was positive environmental and efficiency values supported by the application of operating envelopes in the form of DOEs, and by extrapolation SOEs. DOEs, they explained, could look like a constraint on renewables but could also unlock more capacity on the network and more opportunity for renewable energy use. This intention aligned with householder values shared.

> What it looks like from a customer's perspective and what we're trying to get to is we think there's actually a lot more capacity than what even historical static limits have made available to customers. And so there's a real opportunity here to maximize … distributed energy resources we have on the network. But also the opportunity for an individual customer to benefit from that as well. So I think often people think about dynamic operating envelopes as curtailing or bringing down the amount of solar customers can export, or the amount of load customers, smart load that customers can use. But I think it's also about unlocking on the upper side as well and providing additional opportunity. (stakeholder interview 17.10.22)

While the overarching principle of reducing solar wastage was well supported and relatively clear, there is nuance and divergence around what particular uses of a household's excess solar are deemed appropriate and desirable. Some householders were happy to generate income with their excess energy through an aggregator. Many were interested in the perceived opportunity to "share" their excess energy, often with a particular focus on supporting people in need, and their local communities. Other householders were willing to support the general public with their DER but questioned whether it was actually the general public or energy corporations that would be benefiting from their participation in SOEs. These findings highlight that more nuanced understanding of consumer expectations of SOEs (and DOEs) and clear communications about what SOEs realistically achieve will be essential to mitigate the risk of misalignment of goals between householders and organisations. Misunderstandings and misalignments about goals cause undermine householder support for SOEs.

Despite indications of conditional support for the value propositions SOEs may offer, there co-existed a strong **aversion to the degree of complexity that SOEs introduce**. In terms of a solution paths, householders questioned (asked us, the design team and energy organisations, to take a step back and check) whether complex solutions like operating envelope management solutions are the best way forward (e.g. this was discussed in the household workshop on 26.11.23). This call to step back and assess, in some ways, could be considered as a call to assess costs (and impacts) of the SOE approach over other approaches. The technical analysis undertaken in Converge focused on SOE benefits in terms of the market value that SOEs unlock over DOEs. However, this poses the comparison of DOEs and SOEs against a limited subset of differences (and mainly the benefits). Network assessments have been undertaken to understand whether operating envelope technologies are a strategic and/or cost-effective way forward. Network interest in operating envelope development is due to DOEs and SOEs having the potential to be a least cost option according to their assessment parameter (Converge team internal communications).

The complexity of operating envelopes and SOEs was also reported as a possible barrier for householders in relation to a range of issues that nest around **comprehension, understanding and assessment**. The concerns included: there being a lack of accessible, trustworthy, personalised information to assist householders to make informed choices; not having the time and mental capacity required to self-educate about SOEs and other related systems and technologies; the risks inherent in more complex, integrated systems related both to consumer data privacy, system security and system fragility; and the challenges associated with involving yet another actor (aggregator) in terms of communications, relationships and assurances.

Householders' concerns relating to the complexity of SOEs and their functions was very likely influenced and reinforced by trying to understand DOEs and SOEs and how they worked in a relatively short time (during a workshop or interview). Householders in this instance were focused on SOEs, which have little descriptive information available as yet because of their trial and niche status. However, we could see this concern was based on challenges already experienced with understanding complex services and systems elsewhere, including energy services. There are other mainstream grid integration technologies and systems that we have observed that are complex, have not necessarily been well described in the public realm, and have had difficulties with communication of that complexity to consumers and the impacts from it – SOEs are not a unique case (for example see [29], [41]). Further commentary on communication needs and nuance is relayed in Section 5.3.

An issue repeatedly raised by householders across both interviews and workshops regarded the **social equity implications** of SOE design and implementation. One group of concerns focused on equitable SOE allocations between SOE participants, including those experiencing vulnerabilities. Some householders, across both workshops and interviews, wanted to understand the differentiated impacts of SOEs on DER owners:

- 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 impacted their energy needs (for example those with high energy demands related to age, health or disability).

For some householders, predominantly those participating in workshops, their primary equity concern was in relation to the impact on householders who did not (and perhaps could not) own DER. Some perceived that SOEs would unfairly confer advantage to householders who were already advantaged by their ownership of solar PV and/or batteries. This concern was expressed by the following householder in this way:

> 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 in applying policies to incentivize individualistic approaches (such as installing rooftop PV and batteries) as they may unintentionally lead to an outcome that is detrimental for the broader community. For example, if households with DER chose to disconnect from the grid, the costs of maintaining the grid would be shared between fewer households and those with less means to pay their electricity bills.

The social equity concerns all related closely to questions about what impacts SOEs might have. Interest in better understanding related impacts aligned with stakeholder feedback (as mentioned near the beginning of this section), as they were also generally interested to understand impacts on householders and how that related to social equity during interviews.

A notable **impact** on the minds of stakeholders when thinking about the general validity of SOEs (during interviews) was **regularity of use**. They tended to use DOEs as an analogue here as DOEs were already being applied and were better known than SOEs. There was anticipation that curtailment would not be needed that often and DOEs might only be occasionally applied, and by extrapolation, that there would not be regular use of SOEs. SOEs were anticipated to be used much less than DOEs. Stakeholders thought, therefore, that SOEs may be unnoticeable to consumers. Some stakeholders, however, anticipated that the need to use real-time operating envelopes may grow over time as networks became more constrained (e.g., conversations with stakeholder interview 6.10.22, and with Converge team at focus groups). Stakeholders relatedly spoke of DOEs having staged rollouts and so becoming something more people Australia-wide would have to think about over time.

Constrained networks were seen as **influencing** the development of more dynamic and shaped operating envelopes. These constrained networks were also seen as something that could convince people to take part with DOEs and potentially SOEs. Stakeholders indicated there was likely going to be rollout priorities for more dynamic operating envelopes in areas where networks were constrained. Examples were given of more densely populated areas having constrained networks situations (stakeholder interviews 6.10.22 and 12.10.22). End of feeder network constraints were also mentioned. Where electric vehicles are increasing in numbers the most, these were anticipated to cause constraints that would lead to the use of operating envelope solutions. Indeed, various constraints on the networks were the impetus for South

Australia to proceed with 'flexible exports', and for Queensland to proceed with its Distributed Energy Resource Management System, which are DOE based approaches [42].

Whether householders would care about the rollout of an SOE was questioned by multiple stakeholders. A stakeholder pointed out that a proportion of people were oblivious to solar PV export curtailment and so may not engage much with other curtailment or management issues (stakeholder interview 6.10.22). On the other side, householders active on energy markets, selling their excess energy were known to be engaged and it was anticipated they would notice DOEs and SOEs and possibly be annoyed about curtailment (stakeholder interview 21.10.22). There was anticipation that the majority of consumers would likely not be too stressed about some curtailment from an operating envelope. Whether or not they would be noticed, if DOEs or SOEs were needed or applied, both stakeholders from networks and retailers thought it was still important to communicate what was happening to householders. We discuss communication further in Section 5.3.

A stakeholder with an installation background relayed how **decisions by householders related to SOEs, or DOEs or other CER,** would be made **in the context** of all the other decisions that needed to be made in the wider household context (stakeholder interview 18.10.22). For example, solar installations would be compared with other opportunities, like bathroom upgrades. Other upgrades and options were often more attractive or needed than DER or installing solar. Energy related upgrades weren't as interesting to householders for a number of reasons. Other stakeholders reinforced this point and encouraged any SOE development at scale to consider situations for householders overall, their end goals and the mix of issues they had to consider. In terms of energy related considerations, home energy management systems and previously installed batteries and inverters were noted as interrelated with SOE decisions. Batteries and solar installations were also seen as potential enablers of SOEs, as batteries and solar together would encourage consideration of connecting to an aggregation service (stakeholder interview 6.10.22).

After being presented with the Converge trial findings at their final workshop, stakeholders discussed **which householders the SOE technology might best suit:**

> Are battery users even the right target cohort to have the maximum grid impact? Are solar only households where the benefits will lie? (stakeholder workshop 11.2.24)

These considerations are tied in with the finding that designing SOEs to protect the self-consumption drivers and capabilities of battery owners has a significant impact on SOE performance, as discussed in detail later in this report.

Stakeholders also mentioned that participation in a VPP may not be a binary proposition. It may be that **future SOE participants are subject to a retail tariff.** This tariff could be much like tariffs today but provide services to the wholesale energy market when prices are extreme (high or low) (stakeholder workshop 11.02.2024). Similarly, parts of the SOE approach may be implemented through different mechanisms (e.g. network support and operating envelopes):

> Do you think it's feasible for part of the shaped DOE to be treated as part of the connection agreement (e.g. export) and part to be treated as network support (e.g. load side limits)? (stakeholder workshop 11.2.24)

Suggestions were made that **people might like to opt in and opt out of SOEs** dynamically depending on their needs. For example, certain types of load may be important to people at a certain time. At those times they may opt out of the dynamic operating envelope for a period and then can opt (or automatically) go back in when they do not need the load (stakeholder workshop 11.2.24).

We note here also in terms of overall responses, **commercial applications were noted** by stakeholders as potentially being more important for SOEs than householder CER and more effective because there are less connection points and less end parties to engage with. This was not something pursued further in this particular project but is likely important as SOEs are further developed.

Would householders participate in an SOE?

Householders in workshops were asked about whether they would participate in SOEs. Non-trial participant interviewees were asked why they chose not to participate. Participating interviewees were asked why they participated. When asked whether or not participants would sign up for an SOE, the most prominent factors householders raised were a series of barriers they identified as reducing the likelihood they would (choose to) participate at this stage.

First and foremost, and related to the discussion in the previous section, householders often described **not having enough information to comfortably make a decision about SOE participation**. During interviews with householders (and workshops as well), we needed to spend time introducing SOEs, even to those who had already decided to take part in the trial. We found many participants felt our explanations contained new information for them. This has implications for informed consent about participation in future SOE or similar approaches. We discuss new information, communication and absorbing complex information more in section 5.3.[1]

Householders wanted to be able to assess how participation with SOEs via this trial **would align with their values and drivers**, particularly: self-consumption; equity and fairness; environmental stewardship; and affordability. Values and drivers are outlined further in Section 5.3. Householders also wanted to understand the impact the technology would have on people in circumstances similar to those that interviewees and workshop participants were experiencing. For example, impacts for a person with a disability, consequential necessary energy needs and concessions on energy payments.

As well as wanting information that was accessible and personalised, householders described the importance of **perceived trustworthiness of the information**, which was seen to be linked to whether the provider of the information had commercial interests involved. Trust and

[1] That we needed to impart information about SOEs to conduct the research means that the social research itself was a kind of influence in the communications and assisted in embedding the new knowledge in the community (through our research interactions with participants).

communications are fundamental to the development of SOEs and integrating DER. They are addressed further in section 5.3.

A second common sentiment raised by householders regarding whether they would participate in an SOE was, **'is it worth the effort?'**. Householders identified that with such a complicated technology, developing an adequate understanding to make an informed decision required a significant amount of time and mental capacity. A number of people interviewed described themselves as being educated and highly engaged in this topic and yet still struggling to fully understand the implications of SOEs. Multiple householders identified that these high demands for informed participation would likely exclude a large portion of the population, who currently lack the time or capacity to self-educate about this technology.

Closely related to the above, some householders told us that they **didn't feel they have the time to consider SOEs**. This was echoed by stakeholders who said:

> "I just think they assume, time, interest. They've got a very textbook view of energy consumers that [in] my experience doesn't at all line up with - the busy, distracted, complicated lives people lead." (stakeholder interview – 4.10.22)

For some householders, **key concerns** regarding participating in the SOE trials were related to householder **data privacy, system security and system reliability**. It was identified by participants that an SOE arrangement with an aggregator would involve the sharing of personal data, often over and above the personal data already shared with various organisations in the energy sector. For some householders this was entwined with concerns about cyber security, and aggregators' ability to protect householders' data, and assets, from hackers. Others described the heightened fragility of complex, integrated systems – and described the impact of the recent Optus outage on people's ability to charge their EVs.

A final prominent barrier to participating in an SOE was particular to the group of householders interviewed who did not currently have a relationship with an aggregator. These householders frequently described an **unwillingness to begin a relationship with yet another organisation** in the energy sector. The was due to the unwanted complexity of beginning and maintaining more relationships and associated communications, as well as low levels of trust in the energy sector.

Converge trial participation

Participants who had considered, or been involved with, Converge trials via their batteries provided us with an opportunity to extend on householder reflections on whether they would participate in an SOE or not. With these participants we were able to examine how householders actually did respond when offered the opportunity to participate in an SOE trial and the ongoing trial machinations with batteries.

As detailed in methods (section 2.2) in the subsection participation, a total of 13 householders across 11 households were interviewed about involvement with Converge or consideration of getting involved with it. These householders were all battery owners connected to – one of two – aggregation services involved with Converge trials.

The aggregation services had used different approaches to involve their customers. One had used an invite/opt in approach and one an opt out approach to engaging participants in the

Converge trial. This was because the two aggregation service providers had very different services and products and operating principles. Householders were offered financial incentives to participate in the trial. One aggregator offered a flat benefit of $200, the other offered a fixed payment per kilowatt-hour of battery behaviour change (e.g. battery charge or discharge). Altogether the different products that customers were connected to, the different opt in and opt out approaches and the different reward structures all meant that SOEs were sitting in very different products and contexts.

Of the 11 households, four had participated in the Converge trial and one additional householder had thought they had opted in, but later realized that they hadn't. Both participating and non-participating householders shared insights regarding their motivations behind their trial participation decisions and provided useful feedback for SOE design and implementation.

Amongst the householders who actively decided not to participate in the Converge trial, a **consistent reason** given was that there was **not enough information provided** for them to fully understand the implications of participation. One householder described reading the brochures provided and following the links for further information, but still not having his questions answered. Another identified himself as a nervous investor and described clearly what he would have needed to feel comfortable to sign up:

> a lot of handholding, a lot of information on the table, a lot of reassurance and a lot of demonstration of how things are going to work and what the benefit will be to the individual participant. (householder interview, 18.12.23)

This need for enough information related back to comments already made about communication and SOEs being relatively complex. See Section 5.3 for further discussion of this.

Self-consumption emerged as an important theme running across the householder, stakeholder, and technology discussions in the Converge trial. As indicated earlier in SOEs description in section 4 'Applying SOEs', SOEs are currently designed to assume that dynamic operating envelopes must always allow consumers to self-consume at home before other battery activity. This design decision is supported by consumer research findings from previous trials [1], [29], [41]. Prioritising self-consumption means that capacity allocations in SOEs must include "zero" or the point at which participants are neither importing from nor exporting to the grid. This is illustrated in Figure 8. In this scenario, it is possible to accept 2 kW of network support as it places the import limit at zero kW (or the point at which people are self-consuming). Accepting 3 kW of demand response would place the import limit at negative 1 kW (or only export is a valid action for this consumer).

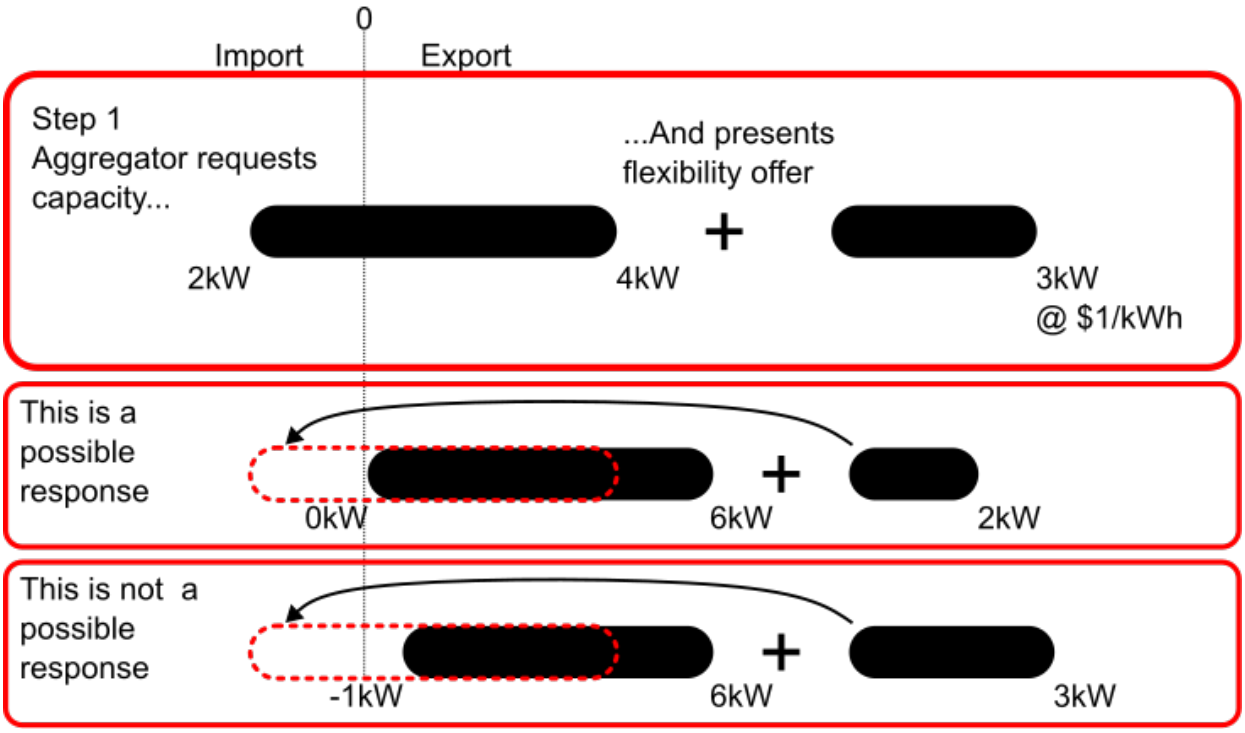

Figure 5 The impact of including the "zero" point in SOEs

The impacts of this self-consumption constraint were extensive in terms of Converge technical findings. The final technical report described this limitation as reducing the amount of network support service the algorithm could procure by nearly an order of magnitude [35][2].

Both householders and stakeholders felt that self-consumption was important. Many of the non-participating householders indicated they would be more open to participating if they were assured that the trial would not reduce their ability to self-consume their energy. Stakeholders were concerned that a push for people to not self-consume would undo long-term advocacy by the energy industry to encourage people to use more of their locally generated energy (such as the information presented in [43]):

> "So I think it needs to be compared to other load control options because battery owners typically are able to self-consume at these high-price times when the network's under pressure and are typically, particularly when they're optimised […] charging at off-peak times when hopefully the grid is not under pressure and that's reflecting in tariffs. So I think that narrative is a little bit network-centric, we just want to be a little bit careful with it" (stakeholder workshop 11.2.24)

[2] The SOE algorithm was the master of the self-consumption decision. A finding of the technical report was that the bids that could be accepted from aggregators was only 10% of the total capacity bid due to the self-consumption design decision in the algorithm. So, this means that aggregators were offering for participants to not self-consume but the algorithm couldn't take up the offer.

So, there is tension between what would be most beneficial for technical performance of the grid and the battery behaviour that aligns with consumer values. Stakeholders advocated for taking this self-consumption value seriously by continuing to integrate it into the design of SOEs, as was done in project Converge.

> Instead of the network saying self-consumption is a problem for me I think probably need to flip it the other way 'round and say if we know that consumers primarily buy batteries or do things because they want to self-consume then the response should be if that's what they want to do what else can we do to meet with that? Then build stuff around it rather than saying that's a problem, how do we fix that? Because I think research and experience indicate that it's very difficult to shift consumers' view on those things. (stakeholder workshop 11.2.24)

There was significant diversity in the level of change in battery behaviour participants saw through trial participation, shown in Table 3 below. Aggregator 2 participants saw more use of their batteries because their payment was upfront. Some participants saw no change in battery behaviour at all, while many saw only very small amounts of change. In part this may help explain why participants were generally fairly relaxed about trial participation as they saw only small changes to battery behaviour. The impacts of the different payment mechanisms can also be clearly seen in these results too. Aggregator 1 participants had very small payments on average because of the small impact on battery behaviour. Aggregator 2 customers received fixed payments, which meant the effective network support payments were highly variable.

Table 3 Financial and technical outcomes form participation for trial participants

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**

The widely varied approaches and outcomes for consumers raises the question around what is a reasonable approach to payments? In the DOE implementations undertaken so far people aren't paid at all, instead the ability to connect and export is proposed to be the main benefit.

Participants in our research were keen that the future energy system was equitable, which calls for the system implementers of SOEs to carefully consider whether SOEs were creating or reinforcing inequities in how they value services.

The technical report shows through modelling that if it is assumed that participants are fully **responsive to prevailing market prices** (and control of solar generation is added), there are **significant benefits to SOEs** (see section 4 of the technical report [35]). Participants were not part of a fully market responsive VPP in Converge. Instead, they were on standard retail tariffs (and so the modelling is showing a *possible* situation)[3]. Market involvement and intentions can clash with self-consumption. From previous research work in DER, DOE and VPP trials household participants identified that market responsive VPP operations clashed with their intentions and were thus challenging [29]. Part of the clash with market intentions these trials found were due to householder intentions to self-consume energy from their solar.

There are ways to **navigate this potential clash**. Stakeholders advised that asking people not to self-consume will require explicit informed consent. It also may mean that there is a different implementation pathway for SOEs that doesn't include self-consumption. This was discussed in our stakeholder workshop:

> SOE is taking the DOE beyond a dynamic expression of a DNSP connection agreement (for which limitations to net zero are appropriate). In my view, anything that goes beyond zero needs to be adequately communicated and compensated, and perhaps treated separately to the DOE. (stakeholder workshop 11.2.24)

Stakeholders suggested at the workshop that SOEs could be optional, or a requirement for certain sorts of customers, depending on the situation. For example, those who have an aggregator relationship may be required to participate in SOEs. Further work is needed to explore the options and possible ways forward.

Other concerns about participation raised by householders included:

- Whether the increased frequency of battery charging and discharging (due to the trial) would reduce their battery longevity;
- Whether they would be financially disadvantaged by participating; and
- How their personal data would be kept private and secure.

Of the four households who did participate in the trial, only two of these had **actively chosen to opt in**. These householders both described their motivations for opting in as primarily to

[3] Although, some participants were technically participating in the contingency FCAS market via their aggregators, this participation had little impact on the day-to-day operation of their battery because FCAS payments are related to technical capability to respond to frequency deviations rather than the response itself.

support the research aims of the Converge trial, and through that, decarbonisation of energy systems. In the words of one participant:

> We were aware that there is research underway to try to work out how to integrate batteries and community batteries and all the rest of it. So we can see our battery is a fairly minuscule part of the whole thing but because we were asked if we wanted to be a part of it we of course said yes because we understand the complexity of trying to introduce the transition, and that any research done is important in helping to iron out all the considerable problems there are because it's a huge thing that's underway. (householder interview, 4.12.23)

This householder expressed disappointment that they had not received any further feedback about the trial in general and particularly about whether the aggregator had accessed their battery or not during the trial. At the time of the householder interviews the trial had been completed but aggregators were not yet informed of the trial outcomes. Therefore, they were not necessarily able to share back insights with their customers at that point. (Although the aggregators would have known from their systems how much network support each participant had provided.)

The two householders who were part of the Converge trial by default (ie they had not opted out) were unaware that they had been part of the trial. They had not noticed any battery impacts over the trial period and did not appear concerned by the realisation that they had been included in this trial. There are a few possibilities worth mentioning in relation to these responses:

- We were engaging with long-term battery owners who had established relationships with their aggregation service. This likely meant the relationship had already been tested to some extent. The aggregator was there to benefit them, they knew this was the case and they had already had the experience of benefits coming from the aggregation relationship.
- SOEs are a fit-in product into the aggregation service, so their actions probably weren't that obvious.
- The self-consumption decision in the algorithm also meant the effect on batteries was not high.

Findings from other trials [29], [41] suggest that the overall nonchalant responses from trial participants would likely have been different if the trial had noticeable impact on their batteries.

Householder experiences of the Converge trial and their decision making about whether or not to participate reinforces our findings about the fundamental role of communication and the influence of values and drivers such as self-consumption, altruism, (data) privacy and financial considerations. Householder responses also suggest that adding a functionality on to an existing set up (that is, adding an SOE to an existing VPP arrangement) in a way that has minimal impact on the consumer resource may not cause significant concern for DER owners. However, it is likely that further examination will be needed to identify whether maintaining a minimal impact on the consumer resource is a realistic outcome for SOEs that are applied to batteries that are not designed for extra market interactions (and are generally for household use).

Niche to scale for SOEs

Much was discussed about the future of DOEs and SOEs. Moving SOEs from a niche solution to mainstream use is the intent. Assessment is needed at this point, at the end of the niche trial, of assess all features and design decisions before moving forward. Stakeholders and householders contributed various insights that can help with consideration of next design phases and identifying SOE roles at scale.

Points made and questions asked in discussions that related to moving forward with SOEs make up a long list. We capture representations of what was noted here:

- Are SOEs just a feature of VPPs?
- Do they need to be a big deal as they aren't physically or systematically anything particularly noticeable – they are designed to do the extra processing with existing systems.
- What do householders need to notice?
- Should incentives related to DOEs and SOEs be, as one stakeholder said, a 'carrot shaped stick? regulatory impost? [An] unpalatable FOE [fixed/static operating envelope] to encourage customers down a certain, responsible path to be part of the solution, not divorced from it.'
- Do SOEs come first or are SOEs and DOEs woven into each other, so are pieces of SOEs being scaled with DOEs anyway? A stakeholder outlined this in an interview:

> So I think if as a concept, the idea is to be able to look more at how that utilization would work from the customer side or you know questions about fairness and then the economics on the customer side. I definitely think that has to be considered. I'm just not sure yet whether that's a layer on top of operating envelopes, dynamic operating envelopes or whether that needs to be part of the input to generate the dynamic operating envelope to start with. (stakeholder interview 21.10.22)

- How could SOEs and DOEs work with community and neighbourhood located batteries? And how could they work with commercial entities and their energy flows?
- Could elements of SOEs become mandatory? A householder in relation to this question said:

> Now I understand that there are benefits, I subsequently read a little bit and I understand there are benefits and even at the time I realised that there would be an eventuality where – presumably would be an eventuality where the ACT Government or somebody else would say sorry but we're going to mandate that you give an energy supplier access to your system and allow them to actually control your system and turn it off if necessary. But I wanted to put that off for as long as possible. (household (a customer of an aggregator) interview, 18.12.23).

A point to highlight is that stakeholders often discussed the **constituent elements of SOEs.** Moving forward, we anticipate that SOEs aim to solve multiple issues and there is potential for expanded and/or disaggregated application of SOEs as its constituent parts. SOEs parts offer a series of intentions that can be expanded and scaled. SOEs and DOEs together have other qualities and benefits and can support alleviation of other stressors on networks aside from simply making guardrails more efficient. For example, DOE approaches have already been used

for emergency control during major grid events [44].Therefore it may be that SOEs have an expanding use case in a future decarbonising grid. This leads to interesting opportunities when thinking about applications. Not all particulars about where, when or why SOEs would be used are set and we can think through further how they may be used at scale. We pursue this line of enquiry in the discussion in Section 6.3.

5.2 Perspectives on intermediaries as part of SOEs

When we spoke to consumers we not only heard about aggregators as important intermediaries, we also heard about intermediaries such as solar installers, early adopters, network customer teams and more being part of household journeys. This included as householders purchased and installed batteries and/or solar systems; rang for help with electricity supply concerns; or established a relationship with an aggregator. The indications are that there are **many important intermediaries** aligns with understanding in socio-technical research and from previous work, which shows the important role of intermediaries for consumers who are taking up DER and for supporting useful technology as it develops (for example [24]).

This section relates insights about intermediaries key to scaling of DOEs and SOEs. Discussion of intermediaries is a huge endeavour and our interim social research report for Converge previously relayed insights about intermediaries relevant to operating envelopes and energy innovation [3]. We therefore focus here on three subsections: relating insights about broader intermediary landscapes, including the need to have representatives for householders; aggregation services as a main contact and potential agents for operating envelopes; and, installers as a ubiquitously important intermediary for DER and grid integration.

The broader intermediary and organisation landscape

There is a relatively **large intermediary landscape**[4] for energy innovation and for operating envelope evolutions. Energy industry organisations and their relationship with the broader DER and operating envelope ecosystems were discussed with stakeholders. Householders were also very aware of key existing intermediaries for them, which included aggregators, retailers, networks, installers, government bodies, community members, community groups, neighbours and even their own household members. Householder information, engagement and learning about energy system and DER integration was commonly filtered through their connected intermediaries, for example, solar installers.

[4] We recognise also that our innovation and research team are part of the intermediary landscape. In some circumstances our team can also have influence in the organisational and householder/consumer spaces. Designers and innovators do always need to work with other organisations who will either accept or decline their ideas. Nevertheless, there is some influence for our group. Social researchers also often have influence through research with participants.

Stakeholders spoke about organisational, and stakeholder **needs to cooperate and collaborate** in this space, rather than compete. There are collective operating envelope and DER integration goals that need to be achieved in what are complex systems. Stakeholders recognised achievement would come as a collective. Examples of key underlying (implied) goals in interviews were to maintain the grid for Australia to use, sustain a system for grid integration, maintain market systems so organisations could sustain their activities, work out ways to keep energy as a public good, and maintain affordability. There was awareness that deciding on a single, or a clear, line of communication and having coordinated definitions was extremely useful, and likely essential, when engaging with consumers. Standards were also recognised as needing further collective development as energy innovation scaled. Standards Australia working groups, ARENA's Distributed Energy Integration Program and the willingness of organisations to allow their staff to attend collective, mostly voluntary, working groups are ways that collective work is being undertaken. This collective work will need to be further supported for operating envelopes and other grid integration to realise their full potential in an equitable way for the community (and to support public good objectives).

Working out values that different organisations hold, and the value chains and value exchanges involved in grid integration and operating envelope solutions was an area discussed with stakeholders as requiring further collective understanding. How retailers and aggregators can find value despite possibly high costs of software was a detailed aspect considered. Previous research has also found value interchanges needing further attention [29].

That intermediaries are willing to talk and negotiate, indicates a willingness to progress innovations and progress solutions for the grid integration space, and we see this positive intention as extremely useful moving forward.

Acceptance of new niche technologies and support to make them scale is something also needed of intermediaries. We relayed thoughts shared by intermediaries about SOE potential earlier in findings.

From discussion with stakeholders, it was clear that as a country there is much to work out and solve as we progress to further grid integration of CER/DER. Stakeholders noted that our organisations and technologies and systems related to grid integration and real time energy supply are all on **a maturity journey**. This means that consumers don't yet have extensive information to base decisions on and we can expect that as this knowledge grows, consumer preferences and expectations may change or be refined. Intermediaries will have roles in enabling these changes to influence the trajectory and value of SOEs over time, as well as ensuring consumer protections also can grow and adapt along this maturity journey.

Many stakeholders we spoke to discussed consumers and ensuring consumers experience only positive impacts as an outcome of DER integration and innovative energy technologies. Our observations over multiple DER/CER grid integration projects have highlighted that it is complicated to anticipate consumer impacts and there can be perverse outcomes. Integrating principles of care with something as complex as grid integration and operating envelopes therefore may need some vigilance over time and checks on how people are faring. In relation to this, stakeholders talked about the need to have **representatives to look out for consumers** and to check systems were reasonable.

Consumer care was relayed as being needed by both householder and stakeholders in various discussions. However, it was not seen as a straightforward role for just one intermediary. It was somewhat unclear as to what care and vigilance for consumers might manifest as (overall). No single entity owns the role of consumer care, or regulatory care for DOEs, yet, and SOEs would have the same issue. This dilemma was clearly related to the lack of maturity in the sector. Energy Consumers Australia takes on aspects of care for consumers in the broader energy system as far as capacity allows; and state ombudsman organisations are acting on more DER/CER related requests from consumers [45], [46]. While these are useful and important intermediaries, stakeholders indicated that other points in the journey required checks and responses for consumers as well. Examples of further consumer related needs are consumers needing a say as designs or solutions are developed, such as through co-design opportunities; customer contacts in retailers and aggregators - who are highly valued by consumers - needing knowledge about new systems and time (and capacity more generally) to engage further with consumers, and consumers needing consideration and action via government policy and regulations.

Technology performance monitoring is also needed for behind the meter household devices as often both householders and organisations can be unaware of technical difficulties, and sometimes for a long period of time. This monitoring has a consumer care and a technology support function. Three examples of where this monitoring is required is to check inverter performance, internet connections are functional, and that the network is supplying electricity cleanly or safely (DER can provide indications related to this). Poor inverter performance can go unseen by participants but is important to know about. Disconnection from the internet, which may be inadvertent, by consumers is also critical for systems to keep working. Who would know of these disfunctions and who would sort the disconnections out are questions currently not easy to answer.

Householders in this research spoke to a range of visibility and invisibilities in the technologies that point to the need for consistent systems for technology function checks. For example:

- In interviews on 30.11.23 and 5.12.23 householders relayed how they were unsure of performance of their technology or unsure how batteries should or would perform under new situations.
- A householder on 7.12.23 explained it took them a year to pattern how the battery was working with household energy use, indicating long time periods might lapse before identifying issues.
- A householder in an interview on 16.1.24 relayed instances of proactive initial technology function checks by organisation and then, conversely, instances where they alerted organisations to investigate electricity issues due to an instinct that emerged from watching her CER. There were complicated issues related to the network that were affecting her technology. And key organisations only realised it due to her alerting them.

Alongside householder data in this project, the Converge team and previous projects [e.g.41] all provide information that points to technology and system checks needing to be undertaken at intervals throughout the life of programs, with householders and organisations both being made aware of outcomes. Further collaboration is needed between intermediary organisations to understand the most consistent and efficient ways to undertake these checks.

Aggregators

Aggregators play a key role in the operation of SOEs as tested in the Converge trial. Introduction of aggregators as a broker or mediator between householders and the energy market is one of the core differentiators between DOEs and SOEs as currently envisaged. Aggregation services are representatives for the consumer in the instance of SOEs, as for other optimisation services. They are also key to optimisation services for DER grid integration.

What householders think about the addition of aggregation service roles are therefore useful to understand. Our householder interviews and workshops revealed a wide range of hopes, concerns and specific feedback based on past experiences with aggregators or generalised from experience with other organisations in the energy sector.

Overall, householders appreciated aggregation services. Aggregators were seen as a reasonable intermediary for the implementation of SOEs by householders who had existing relationships with an aggregator. Aggregators were being positioned as experts. For example:

> They [aggregators] are going to be the experts in that area so you don't actually have to become an expert, you can rely on their expertise and lean on them to do a lot of that negotiation 'cause I don't want to be an expert in the energy market, I have my aggregator who talks to me about what's the best deal for me. (householder interview, 10.12.23)

Some householders were clearly in favour of having aggregators utilise their expertise to get additional benefits out of home batteries and solar. They saw this as an opportunity to remove some of the growing demands on themselves to build up personal skills and understanding of the complicated workings of the energy market. Several interviewees were participating in Virtual Power Plants through aggregators and reported appreciating and acting on communications from their aggregators when flagging optimal times to consume energy. Some interviewees described very positive experiences with energy organisations (including, but not exclusively, aggregators) that provided extensive, personalised support to navigate what DER systems and arrangements would best meet the householders' current and future energy needs. However, two significant concerns that were repeatedly raised were communication and trustworthiness. These are outlined below in relation to householder relationships with aggregators and returned to with a broader, energy system lens in section 5.3.

Better communication was sought relating to operating envelopes that are part of aggregation services. The most common issue raised by householders who had an existing relationship with an aggregator, was the desire for more and/or clearer information.

> The more sophisticated the system the more the communication needs to be stepped up with – well are we users? I don't know but anyway with the households that are feeding into the system. I think we're entitled to know. I mean a lot of people will probably think oh god, another email about this but there will be a certain cohort that will be tracking it closely. (householder interview, 4.12.23)

Multiple householders described some degree of confusion regarding the role and actions of their aggregators as expressed by these two interviewees:

> I think they monitor it [the battery] but I'm not exactly sure what they do. (householder interview, 10.12.23)
>
> To be honest nobody's really explained what [my aggregator] does. All they say is [my aggregator] basically optimises your battery performance... (householder interview, 7.12.23).

Some DER owners desired more detailed communication about both the expected and actual interactions between their batteries and the aggregators. For example, whether a particular grid event or need was anticipated, what the potential battery demands were, and then feedback about what actual battery demands and contribution had been. Providing householders with clear and sufficient information about intended and actual use of their DER is essential in promoting transparency and providing assurance regarding the trustworthiness of an aggregator. This request for more communication is a consistent finding across other DER, DOE and VPP trials (for example see [29], [41]).

Householders weren't sure that aggregators necessarily knew their preferences. Assumptions about preferences of consumers have been integrated into aggregation services and into algorithms involved in DER grid integration. Algorithms effectively act as an agent for householders, have set parameters that direct what 'decisions' are made, and include assumptions about consumer preferences. Algorithms are commonly hidden and therefore are difficult to interrogate by consumers and stakeholders involved. We have observed through multiple DER/CER trials that various parties involved often assume algorithms are impartial translators. In reality, the set parameters used mean algorithms assess, weigh, and decide in very specific ways. This decision-making role is extremely useful and allows householders to be involved in a complex market in a relatively protected way, which can be very positive. But, algorithms have to make decisions based on what they can measure in the system, which is focused on price and financial value of energy interchange. This focus can misrepresent householder preferences. Householders often intuit this is the case and talk to us about their concerns about their preferences and values in DER integration research, as they did in this research. Stakeholders also raised allocation decisions as important to interrogate in this research.

Competing interests were raised as important and relate to the consumer preferences point made just above and earlier discussions (in section 5.1) about values and preferences. Previous studies have shown that aggregators used price as a key guide to how they decided on consumer benefit, however these studies also found that consumers have a broader set of driving values behind having DER/CER [47]. The CONSORT Bruny Island Battery Trial, for example, found that the purely financial based optimisation offered by the aggregator did not always result in battery behaviour that enabled other values (such as, self-sufficiency, or emergency preparation) [41]. Another example emergent from Converge is that self-consumption was important to the participants we spoke to, but aggregators were submitting offers that would result in participants not self-consuming (see section 5.1 for more exploration of this factor). The self-consumption outcomes of the Converge trial instead was a result of an underpinning assumption in the SOE algorithm.

Trustworthiness layered in with competing interest concerns were repeatedly raised by householders that didn't yet have home batteries or a relationship with an aggregator.

Householders identified that as for-profit corporations, aggregators would have obligations towards their shareholders that wouldn't always allow them to prioritise the best interests of their householder customer base.

> None of this should have been privatised in the first place, it's critical infrastructure that should have remained owned by the people or the government, however that would be best structured. But the fact that it's now part of private enterprise makes it much more difficult 'cause you've got different interests trying to achieve different things, really, for their own shareholders where really the critical shareholder in all of this is the public. (householder interview, 10.12.23)

Householders with aggregation services did not tend to focus on aggregators' competing interest. This is likely due to householders already having assessed their aggregation service, made the decision to take part in aggregation services, and likely profited financially from the aggregator relationship.

An aligned theme was raised in the stakeholder workshops, summarised by the question: **is it reasonable to expect an aggregator to represent consumer values to the SOE engine?** Aggregators present specific product propositions and are faced with practical and commercial barriers that can get in the way of meeting or representing further consumer values. Understanding consumer values is potentially a complex process, which is costly and could make products harder to achieve or administer. Similarly, this is likely to reduce the flexibility and amount of energy services aggregators could offer the market, and thus potentially also reduce their revenue. This creates tension between understanding and communicating values, being the representative and agent of householders, and commercial drivers.

A number of householders highlighted that they don't trust information provided by for-profit companies about the products and services they offer – which would include aggregators describing SOE offerings. Householders' prior negative experiences with other energy industry organisations, including retailers and installers, was often front of mind when assessing the role of aggregators within SOEs. Two householders highlighted that, for them, aggregator's trustworthiness was also assessed in terms of their perceived capability to protect the privacy and security of the householder's personal energy use data that would flow to an aggregator upon joining a VPP or SOE.

Further interrogation is needed of how consumer preferences can be considered around the now maturing service of DER/CER aggregation. Aggregators can look after householders in certain ways, but is it reasonable for our energy system in Australia to expect aggregators to have the knowledge, desire, or the position in the value exchange, to be impartial agents who take care of and communicate all consumer preferences? We see this as requiring further national conversation.

Related to reactions householders had about complexity being a barrier, householders also **asked if another organisation might be needed** in the mix of energy provision. For householders without batteries (and no existing relationship with an aggregator), the SOE requirement for an aggregator-householder relationship was seen as adding in another layer of

complexity for householders that was not necessarily justified. The complexity started at the initial stage of choosing a suitable aggregator as described by this householder:

> You've got to pick your aggregator and it's hard enough picking a super fund let alone picking an energy aggregator. (householder workshop A, 26.11.23)

However, even after an aggregator was chosen, householders with aggregator relationships then described the significant task of having to manage and understand multiple energy related Apps and communications. This included uploading different information to different organisations' Apps and having to troubleshoot across the services. In addition, the aforementioned data privacy concerns were elevated by the reality that people with home batteries are often already sharing their personal data with a number of other energy organisations including retailers, battery providers, and smart technology providers.

Installers

Installers are a ubiquitously important intermediary for DER and grid integration, but in our experience in research are underrepresented in data and appear also to sometimes be overlooked when people are assessing energy industry changes needed.

A stakeholder shared some thoughts about installers in relation to DOEs and SOEs that assist us to capture **a range of issues that need focus** as the Australian energy transition progresses, and operating envelopes evolve:

> You know solar installations are pretty competitive market, and do installers even have the resources to cope with this? Because if you're average householder sees something happening with their system and they don't know what it is, and …[there's not] the Australian standard levels of curtailment, and check of operation … already in place. And then if you layer that with dynamic operating envelopes. The first person they're going to install, is to call their installer and say 'Why isn't my system working?', 'What are you doing?' and 'Why isn't my system working?' … And that's time a lot of these companies are not going to have. And so that might even lead to noncompliance because when faced with breaking the law and doing a noncompliant setting up of a system, versus having to cope with an avalanche of customer complaints and queries, they just mightn't have the option. So, it's bad both ways. (stakeholder interview 12.10.22)

An installer (interview 19.10.22) relayed the **constantly changing, regulated and consumer contact heavy context** they worked within day to day. The installer's company was proactive and engaged with emerging technologies and grid integration. They reported needing to maintain understanding of old and new technologies and changing standards, supply and regulation environments. New technologies and standards meant extra training for staff (on top of standard requirements), substantial upskilling, and leaders in the company needing to undertake supportive skill development checks during installations. These requirements have been growing for installers in this changing installation landscape.

Additionally, installers have been moving from a mainly electrical competency-based industry to one that now needs to actively incorporate information technology competencies and more complicated power system integration competencies. This **increase in required competencies**

has been occurring over approximately the last 10 years. Many installers were likely trained before the competencies became necessary and so have had to undertake learning on the go and to pivot in their work knowledge and practices.

Installers are also, as the stakeholder quote above pointed out, **the interface for consumers.** Installers may go out to a new installation job but end up having to assess and involve themselves with challenging historical installations done by others, explain the complex work of grid integration, and face in many instances creative installation environments (as all home are unique). Customer service is a part of what installers do, but it was pointed out that installers often do the engagement work that should be the responsibility of other organisations in relation to DER and CER grid integrated systems. As often relatively small companies, installers **may not have the capacity to support the entirety of consumer engagement needed**.

Customer care and information needs, and it being bigger than any one organisation, is recognised by Energy Consumers Australia and other advocacy organisations, who have been motivating action to **develop a central organisation** to help people navigate through energy systems and energy system evolutions [48]. This is one way that installers may see some reduced pressure and consumers may access useful and more impartial information.

5.3 Insights for CER grid integrated futures

SOEs and DOEs sit within a vision of the future energy system in which DER is highly integrated with the grid. The Converge social research had an extra mandate to capture householder perspectives on a DER grid integrated future and the energy transition. The above findings relay insights relevant to both operating envelopes and grid integration and we report on grid integration further in this section, with an emphasis on insights provided by householders. This section relays factors householders shared that influence grid integration futures in their minds, and covers values and drivers; household energy management factors; expectations held of the energy system; and actions that can enable communication and trust.

Household values and drivers

Values are a commonly interrogated influence in social change research because of their influence as a fundamental driver of action. Demski et al (2015) explain:

> Values refer to beliefs about how the world should be, and capture personal and cultural principles about states of existence and modes of conduct; they are ideals about what ought to happen regardless of situational context."[49, p. 60].

Investigating core, recurring public values proves very useful when seeking to understand what kind of electricity system the Australian public wants and what best serves them. Asking for values to be identified by householders is particularly useful when we are also asking them to examine and respond to an emerging, mostly unknown and complicated technology such as SOEs. Values discussions assisted householders to provide explicit feedback on their points of views of DOEs and SOEs in a short timeframe.

We mentioned values and drivers at points throughout the findings on operating envelopes and provide more detail here by highlighting key values and drivers raised by householders in

relation to grid connections, operating envelopes, and the energy transition. We focus on the most emphasised values 'groups', which are equity, environmental stewardship, self-consumption, and affordability. The energy sector can use an understanding of householder values to check how industry visions of the energy transition align (or otherwise) with core householder values, and what impact misalignments may have on household involvement in grid integration into the future.

Values related to social equity

The most emphasised group of values referenced by householders in our interviews and focus groups related to equity, justice and collective care. These values relate back to ensuring that the electricity system is fair and available for all to use. This nest of values were mentioned 42 times across the energy customer interviews and workshops, indicating that overall, there was a strong desire to ensure no one is left behind in the energy transition. Two dimensions emerged as prominent. These are that householders hold expectations that the energy system is socially equitable; and DER owners want to contribute to the greater good of their community.

Interviewees and workshop participants alike raised several related points about **wanting the energy system to be designed to be equitable**, catering for everyone's diverse needs, protecting people with vulnerabilities and ensuring no one is disadvantaged or left behind. Some participants spoke of a hierarchy of needs with preference to be given to more vulnerable members of society. For example, the electricity needs of hospitals and nursing homes should be ranked above restaurant air conditioning. One workshop participant (workshop on 26.11.23) suggested 'ceilings' or constraints should be placed on air-conditioning settings in shopping centres, restaurants and office buildings.

Householder intentions for fairness and equity have emerged clearly in other social research in our Program, captured both through collective social research community of practice conversations and via reporting in research (for e.g. [47]). Our Program team reports that sentiment shows most energy consumers we engage with support system design that is fair and equitable, but the values come be enacted through various processes.

> Some may think a centrally controlled (bureaucratic) system will best provide this, others will put faith in markets, still others will look to community autonomy or communing. This will be influenced by worldview and past experiences. (Wendy Russell, in social science group Community of Practice communication internal to BSGIP, with permission)

For some DER owners that were interviewed, **a benefit to owning DER is the belief that they can contribute to the greater good** by supporting decarbonisation of the energy system and potentially by sharing their excess energy with their community. This group of DER owners are likely to think favourably of new technologies or energy system arrangements that enable them to contribute positively to society, or 'do their bit'.

> This is what society is 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)

> But if I have a solar system I want to be told I'm doing something good and that's pretty much what I want other than a financial incentive. (householder workshop C, 26.11.23)

The emphasis on equity and fairness also emerged from previous research undertaken by researchers in our program with the Victorian energy and water ombudsman [47].

Environmental stewardship

The threat posed by climate change is an existential concern for many householders. The **importance placed on taking care of the environment and addressing climate change** were apparent in interviews and focus groups and were the second most referenced group of values, with 22 mentions.

Many Australians are affected by dread of what changing climates and environmentally degraded futures will be and bring. Impact of this anxiety and distress on the mental health of Australians is well reported [50]. Many of the householders we spoke to were clearly motivated by a desire to limit their environmental footprint and alter their behaviour to help conserve the environment. Electricity use and management was a way householders helped to mitigate climate change.

> Well it's about five years ago now I think that we've had the system but it was mainly because of climate change and the fact that we wanted to do our bit. (householder interview, 10.12.23)

These environmental motivations mean that it was important to many householders that whatever they (and by extension the algorithm) was doing was environmentally supportive and actively reduced the net carbon impact of the electricity market.

Self-consumption

A primary motivator for DER owners, particularly those with batteries, was self-consumption:

> What's the first principle of having your own solar? Self-consumption. (householder workshop A, 26.11.23)

In the context of DER ownership and grid integration, there is a closely interlinked group of values that centre on **desires for self-sufficiency, energy independence, and autonomy.** For those with the means to purchase DER, we saw that there were strong desires to take control over their energy production and consumption patterns. There were 18 mentions by DER owners relating to this value group. As not all householders that we interviewed owned DER, this may account for why this ranks third in the list of values. If all householders interviewed owned DER than this value group may have ranked higher.

DER owners made the point that before they would consider sharing their excess energy, it was very important to them to understand that their energy needs were catered for first and foremost. This highlighted concerns with losing control of their energy and/or the perception that they may not have enough energy as and when they require it.

People we have spoken to value this nest of (what can also be described as) conditions because they support personal action and agency. Autonomy was explored by Freidman in an article on technology and values and argues that it is a condition 'fundamental to human flourishing and self-development'[51]. This value set and the reasons behind them also align with the findings of other projects [29], [41].

Affordability

Affordability can be considered both a practical fiscal aim and an underlying value. Households value affordability as a means by which their needs are met. The affordability of a solar PV system or a home battery is relative to financial, and arguably also other, circumstances of a household. Whilst the price of solar PV has dropped significantly over the past decade, it is still out of reach for many low-income earners. The price of home batteries has not dropped in price much, or at all, in the same time and they are seen as very expensive items to purchase. One workshop participant mentioned that he was advised by 'most solar companies' not to purchase a battery at this stage because of their prohibitive cost and because most batteries people were purchasing for residential properties were not going to be able to store enough electricity to power an entire home for a long period (householder workshop A 26.11.23).

Financial incentives were one factor that contributed to householder decisions to purchase DER. Householders who owned DER were asked about the affordability of the new energy technologies that they had purchased. Discussions were had around subsidies and interest free loans common across the battery owners in Converge. Reference was made to the ACT Government's Next Generation Energy Storage (Next Gen) program which, when running offered a rebate of 50% off the battery price up to a maximum of $3,500. This program required installation of "smart" battery systems with aggregator control [52]. Also referenced as a factor in the decision-making process was the Brighte Scheme offering 0% interest loans of between $2,000 and $15,000, as part of the ACT Government's Sustainable Household Scheme [5]. Both of these schemes contributed to the affordability of CER and were factored into purchasing decisions made by CER owners.

Industry anticipate that customers respond to financial incentives such as rebates and interest free loans when making decisions about purchasing new energy technologies. Indeed, there is evidence that certain larger incentives, such as subsidies, are relatively influential [52]. However, it is important to understand that DER owners we interviewed chose to purchase their solar PV and batteries for a myriad of reasons. Affordability and large subsidies were but two of the factors that drove interest and then influenced their purchasing decisions, and the effect of anything less than a large subsidy is unclear (as also supported by previous projects, see [29], [41]).

[5] Information of the current program can be accessed at "The ACT Sustainable Household Scheme." Brighte. Accessed May 13, 2024. https://brighte.com.au/act-sustainable-household-scheme

Household energy management

Throughout the interviews and workshops, householders often spontaneously **described significant actions they had undertaken to change their energy use** in their homes and communities. They described concerted efforts and commitment to reducing their carbon emissions over many years through energy efficiency measures and retrofits, home electrification, and adoption of energy technologies, including PV, batteries, EVs and home energy automation systems. For some this commitment had underpinned decisions to move homes. For others it required drawing on superannuation to fund their energy investments. Whilst for others it had required persistence to address significant problems with their installations and/or connections. One participant spoke of these diverse situations:

> I guess the lesson is that everybody's different. Everybody's starting at a different point and everybody's got different needs and that's the puzzle you got to solve. (householder workshop A, 26.22.23)

These experiences highlighted a range of relevant, practical challenges householders faced as they attempted to make changes to their homes and behaviours. These included practical, physical limitations relating to existing homes, lack of appropriate governance or policy at multiple social scales (for example for EV charging in apartment buildings), limited diversity in product offerings (wheelchair accessible EVs and electric utes are currently unaffordable), and dealing with organisations that are still developing the skills and capabilities to manage teething issues during energy system changes. These experiences highlight the scale of responsibility and burden householders are being asked to shoulder in the name of the energy transition, particularly early adopters.

In what were wide-ranging discussions, householders **frequently talked about energy efficiency focused home improvements as actions they had undertaken**. They also highlighted advice from peer learning communities (such as the Facebook group "My Efficient Electric Home") that home energy efficiency measures should be the first priority before householders invest in home electrification and rooftop PV. One participant shared a concern that in a largely for-profit energy system, there was actually little incentive for the energy industry to reduce overall energy demand through home efficiency measures. From a householder behavioural perspective, there is also emerging evidence that an unintended outcome of rooftop PV installation is it creates a disinclination for householders to be careful with their energy use during daylight hours.

> Well yeah, when you use electricity in the day I don't really care too much about efficiency, I've got so much excess. (householder workshop A, 26.11.23)

Another relevant theme emerging from these discussions was **the impact that installing solar PV, and/or batteries (or having better access to energy use data as a result) had on people's energy use over time.** Householders described going on a learning journey after they installed their CER, learning both about how much energy various appliances used as well as attempting to shift energy use to daylight hours as much as possible to maximise self-consumption. Learning about and using the delay start function on appliances was repeatedly referenced as important in this space. Some behavioural shifts were trialled and then given up when householders realised the change didn't work for them. After over a year (many years for some), much of these new energy use patterns and understanding of their PV and battery had

become intuitive for people. Importantly, multiple householders described that after this period of learning and change, they had now made all the changes to their energy use that were feasible and they didn't see additional changes as possible.

> We've done as much as we can other than freezing in winter in the evenings and we're not willing to shift that. (householder workshop A, 26.22.23)

These householder experiences of testing out energy use changes provide useful insights on the related topics of demand flexibility and demand management. They highlight that not all households have the same capacity to be "flexible" and shift their timing of energy use. Their experiences indicate that changing energy use habits takes time and motivation, which was often tied up with decisions to install DER and the associated motivation to then self-consume energy. As discussions turned to demand management, there was a similar theme around motivation, or specifically needing a clear justification as to why such a significant action (as controlling a households' energy use) was needed at that time, and whether an alternative was possible. Whilst some householders were open to having certain appliances curtailed in order to provide clear benefits to the community, others felt that demand management would be a step too far. One EV owner felt that having a restriction on when he was able to charge his EV would not only be personally unpalatable, it would have negative impacts on broader EV uptake.

Amongst householders who owned both batteries and solar PV, **there were a sub-group who were increasingly independent from the grid**. The perspectives shared by this cohort indicate a potential unintended consequence of promoting home battery uptake is that battery owners may begin to disconnect from the grid if they are dissatisfied with the financial implications, degree of control (demand management) or other obligations related to grid connection. One point raised during householder interviews was the decreasing value of paying for grid connection as a household becomes increasingly self-reliant in terms of energy:

> …because of the few minutes in the year that I need power from the grid I'm paying to have a connection. (householder workshop C, 26.11.23)

Another householder described how water supply fees had increased after a period where householders had reduced their water consumption habits due to public education campaigns after a drought. They expected the same to happen with electricity as demand reduced due to increasing CER uptake and behavioural measures. For another householder the description of operating envelopes to manage grid integration of DER elicited a strong reaction:

> I mean all three of those scenarios just made me want to go 'how quickly can I go off-grid?' I'll be happy to have a diesel generator for when I need it but to me it creates an incentive to go I want to be completely off-grid in the middle of Canberra. (householder workshop A, 26.11.23)

Household expectations of the energy system and its design

During interviews and workshops with householders, researchers provided an overview of network challenges and opportunities related to the integration of CER into the grid. Householders were given the opportunity to share their thoughts on the changing energy system, how the electricity network should be managed and the principles they would like to see reflected in the way that CER are integrated into the energy system. The two main

overarching themes evident in householder responses to this aspect of interviews and workshop discussions were: managing the energy system as a collective good; and the role of energy system experts.

The energy system as a collective good

Building on values described earlier, energy as a collective good was discussed throughout consultations as a principle to design to and a performance criteria people expected the energy system to be working toward.

> I just come at this from the perspective that we're in a developed first world country and utilities should be a social good and an expectation. I don't think it's reasonable for a company to hold off on building the necessary infrastructure to futureproof the grid and instead to ask people to forego their hot shower or not use the AC 'til after 8pm or whatever comfort sacrifice or behaviour change they're requesting. I mean ultimately when it comes down to it the whole purpose of services, of utilities is to make people's lives better and that should be the focus and goal and if they can't do that and make a profit then their business model is wrong. (householder workshop, 12.12.23)

There was strong sentiment that **the energy system should be** managed as a collective good and underpinned by a commitment to **working for the good of all citizens**. Householders described the importance of actively seeking and incorporating the needs and perspectives of diverse groups within society and directing collective resources towards those with vulnerabilities. In addition to equity considerations, householders supported taking a whole-of-community approach to network management and transitions. They questioned whether an individualised response (such as promoting DER) was the optimal scale to direct limited resources towards, for example the rare earth metals needed in batteries, to achieve the greatest good.

Additionally, as mentioned in the values section above, many householders were also driven by concern for the environment and identified that reducing the environmental impact of the electricity market and use should also be a key principle in energy system decision making. Prioritising equitable public benefits and the environment were perceived as being at odds with some of the commercial drivers within the current energy sector. Householders described 'escalator' pricing tactics by energy retailers and the recent Qantas controversy in which the airline sold tickets to already cancelled flights as examples of corporations prioritising profits at the expense of consumers.

Energy system experts as key agents, with consumer input at important points

Network management, integration of CER into the grid, and energy system decarbonisation are inherently complex topics that rely on deep subject expertise across fields of engineering, physics, economics and the social sciences. Householders often acknowledged the crucial and challenging role that energy system experts play in recommending paths forward and making decisions about the current and future design of our electricity grid. **Householders expected energy system experts to grapple with and act on preparing the grid** for the uncertainties of the future, to attempt to anticipate unintended consequences of new technologies or policies, and to consider opportunities for resource reuse.

Whilst householders wanted experts to lead the way, they wanted assurance that decisions were based on both evidence as well as the values and expectations of the community. **Householders also wanted opportunities to provide input** into network planning and energy transition efforts and felt that substantial consumer engagement and two-way information exchange would need to be an ongoing feature in a grid that integrated householders CER. They recognised that in-depth engagement would need to be an option, rather than an expectation, for the broader population of householders. This aligns with findings of previous research that specifically considered householder perspectives on decision making [53].

The role of communications in increasing energy sector transparency, ensuring consumer input where needed and identifying implications for building and maintaining trust is so crucial that it is discussed further in the next section.

Communications and trust for grid integrated futures

We have relayed points about the need for improved, appropriately targeted communication approaches above and refer in a more detailed way to it here. Whether or not to communicate simplified or detailed explanations of the functions of SOEs and other grid integration/energy management technologies, and how this would affect possible consumer interest and participation, were conversations repeated throughout Converge social research.

Communication approaches

When considering how to better communicate **a principles-based approach to complex detail was suggested**. The National Electricity Market is a complex, multifaceted system. Consequently, it is shrouded in mystery for many householders. Algorithms used for DER/CER integration provided a specific example of a complex aspect of DER integration and one stakeholder suggested communications start by asking consumers what they are interested in knowing, 'is it financial, community, something else?' (stakeholder workshop, 11.2.24). Another stakeholder recommended shifting the focus from the workings of the algorithm to the outcomes it is designed to produce, 'Algorithm schmalgorithm. Communicate the benefits the algorithms deliver (to the customer, to the system, to the community) and deliver on them' (stakeholder workshop, 11.2.24). Providing information about the principles and parameters the algorithm was developed to align with was also suggested.

Opinions on **what level and types of information should be provided varied greatly** and at the same time recognised the great range of information needs and interest that exists across the population. Stakeholders referenced the differing needs of subgroups including the 'mass market' which was perceived to entail consumers that were 'not interested at all other than WWIIF [What's In It For Me]' and the '3% of people who are really into what their PV and battery's doing and how much kilowatts this and that' (stakeholder workshop, 11.2.24). So, there was acknowledgement that most people don't want to think much about electricity but there is a range and that communication tactics needed to cover the range of communications needed. As such it was repeatedly acknowledged that detailed information should be available, in an understandable format, for those who are interested. Arguably also, as the electricity

sector is utilising the CER owners' assets there is an obligation to clearly share detail with consumers.

Participation in CER/DER integration, householders reasonably pointed out, needed to begin with understanding what is involved. Interviews and workshops with householders showed that on the whole there is a willingness to be involved in shared energy generation and grid integration as long as they know what they are getting into. **Consumers clearly communicated that while there is complexity, they do want to know about the technologies being installed that affect them and their communities**. Seven interviews in this project support this, with one interviewee describing how she had joined a DNSP community panel in order to learn more about CER and grid integration. Another two interviewees made specific suggestions about the types of (presentations of) information they would find helpful (these were narrative scenarios and demonstrations). This phenomenon of consumers seeking to know more despite technical complexity was also clear in recent Project Symphony work [29].

A communications expert with understanding of DOEs, SOEs and aggregation confirmed that in their opinion householders did need to be well informed, both to explain what is going on and to allay fears (stakeholder workshop 11.2.24). Fears, they further explained, were often based on mistruths about, for example, feeling surveyed through monitoring equipment used for DER/CER integration.

Stakeholders are **keen to know what the householders need to know and how to pitch it.** The need for information and the **difficulty providing enough of the right information** during a trial are commonly observed challenges in DER related energy trials [29], [41]. Some of these challenges and perhaps greater communication needs **are due to trial contexts**. As one stakeholder pointed out 'these people were being paid to be part of a pilot project so they would want to know more information around what that meant' (stakeholder workshop 11.2.24). Another stakeholder highlighted the point-in-time related challenges of providing information about cutting edge technologies such as SOEs:

> This is a very complex and emerging space, consumers I don't think have a huge base of information to work on and so I expect that over time knowledge will grow. (stakeholder workshop, 11.2.24)

A stakeholder relayed some of the difficulties they had with working out what needed to be said in relation to real time operating envelopes:

> I think the message to consumers … I don't think that's there yet. If you have to go to Mum and Dad and say, 'Oh, you know you can change these tariffs and go on to a dynamic operating envelope', I'd just get blank looks. Right? Like, 'What are you talking about?' And then and if the default position is just to is to say 'Well, let's curtail and control you', then my Dad's heckles would be up straight away. (stakeholder interview, 12.10.22)

There is also awareness that **the difference of aims between stakeholders and consumers can get in the way of communication**. A DNSP stakeholder explained they are looking at how to

ensure the 'network can still keep operating safely, performing properly' with operating envelopes but the customer communications team asked, 'what's in it for the customer?' (about the value proposition for the consumer). From the customer perspective dynamic and/or shaped operating envelopes 'certainly enable bigger [PV] systems that they want, that they can do more with, but it does mean that those critical times, it can be managed.' However, this stakeholder thought that there 'isn't really necessarily a great understanding' of how to communicate the value and need to consumers and that:

> …as an industry, maybe we've done ourselves an injustice in that it really was put solar on, you know, the more the merrier, fill your roof and then great, you know, export to the grid, whatever you don't use. And now, all of a sudden, we're like oh-kay, we can't, we can't have everyone doing that all the time. (stakeholder interview, 21.10.22)

Variance of opinions and dilemmas about how and what to communicate to consumers is not just isolated to DER/CER integration in the energy system. Targeting communications and getting the right balance of engagement is difficult across the energy industry throughout innovation, advocacy and energy communities[6].

Trust generation through high quality communication

In any conversation about the importance of communication, **trust is an important factor.** Trust in a new technology can be earned through evidence and through interaction and information exchange with other people. Clear and transparent communication is a very useful tool for building trust. Trust, or lack thereof, is a major issue for the energy system and energy industries [54] and our research reaffirmed this.

Interviewees and workshop participants expressed the desire to feel confident that they understand enough and/or trusted the aggregator enough to make decisions on their behalf. In our householder interviews, distrust was mentioned 14 times and trust, just twice. Distrust was raised in relation to electricity retailers, solar installers, 'big business', and anyone trying to sell something. Distrust most often related to the perception that industry companies' main purpose is to make a profit, and that this was opposed to having the customers' best interests at heart. One householder admitted to distrusting people trying to sell things in general (in workshop 26.11.23). An earlier experience of a solar installer suggesting a householder not read

[6] Multiple organisations are aware of the need for better communication. For example, how and what to communicate of energy changes and futures was a topic in the most recent Energy Consumers Australia Foresighting Forum in February 2024 [48]. And, an AER review of consumer protections document stated the 'market complexity is harming the ability of consumers to make informed decisions about their energy services. Unless these consumer risks are addressed in a timely manner, consumer trust in new energy services will be eroded'(https://www.aer.gov.au/system/files/2023-12/AER%20-%20Review%20of%20consumer%20protections%20for%20future%20energy%20services%20-%20Final%20advice%20-%20November%202023.pdf accessed 13 May 2024). Trust is discussed in relation to communication in the next subsection.

a contract and just go ahead on trust was given by another household participant as a reason for distrusting an(other) organisation involved in grid integration (later on).

> I got to the point where my solar installer just simply said don't bother reading our Ts and Cs 'cause it'll just upset you, it'll just put you off, take it on trust. So I didn't want to have to go through that process yet again with a proposal to join a VPP and whatever else that entailed. So I just didn't need a lot more longwinded, legalistic documentation that preserved everybody else's rights except mine and I didn't pursue it any further. (interview 18.12.23)

The mentions of trust in our interviews related to companies who were perceived as experts and whose trustworthiness was established through good communication. One DER owner expressed how pleased he was with his chosen solar installer as they took the time to explain information and answer concerns (18.12.23). He spoke of how much he appreciated the extensive discussions that were had, prior to him making a decision to utilise that installer's services. Participant perceptions of aggregators are another example where trust is important, as discussed in Section 5.2. Overall it was reported that alongside excellent communication, transparency and taking the time to build rapport contributed to the establishment of trust.

Details for improved communications

Features and principles that can generate appropriate and useful communication emerged from interviews and workshops with consumers. These included communicating to householders:

- to make the invisible visible;
- to explain the 'why' or the purpose of DER integration and operating envelopes;
- using accessible language (or plain language);
- what will occur or is occurring, including notifications of what happens as the system is in use, where energy is going when energy is shared, and scenarios that provide examples; and
- how decisions are made in the grid integration and operating envelopes systems.

Communications help make the complex and invisible visible. This can be achieved by relaying key information about the who, what, when, where, and why aspects of grid integration phenomena. Explaining the 'why' is critically important. As we have noted above, consumers make decisions to take part based on their values and drivers. Some customers noted they would like reassurance that what they are getting, or have gotten, involved in, with DER/CER integration and operating envelopes, makes a difference to other people and the community, not just big business. Letting people know when they can feel good about their contributions and connections can lead to more motivation to be and stay involved.

The use of in accessible language was raised as an issue. For most participants the terms 'fixed operating envelopes', 'dynamic operating envelopes' and 'shaped operating envelopes' were inaccessible terms. Householders were commonly keen to see plainer and more accessible language used.

Knowing what is going to, or is, occurring was of interest. Notification upfront about when organisations are using householders' electricity was relayed in the interviews and workshops, as an example of where trust can be generated through communication. Some householders

expressed a desire to know where their energy is going as well – to whom and when and for what. For some there was a preference for energy to be consumed closer to home, for example within Canberra, or by neighbours or social enterprises. For example:

> I guess just that notification that you're doing it…make sure that you're keeping them (customers) advised of yes, we are taking your resources at this point in time and the reason why. So for me that would be communication again, just to let people know…how much was taken and how it actually helped would be nice to know. Your electricity helped in doing XYZ, it's a good news story." (householder interview, 24.1.23)

One interviewee suggested the use of scenarios as an educational tool to provide examples of what might happen in certain household types.

> I understand how the connections work but there was no sense of how does it work for a family. Is it different for a family of four? Is it different if I'm not home all day? There was no sense of scenario. (householder interview, 20.12.23)

Some householders also commented on being interested in aggregators communicating how they are making decisions, and how their energy is being distributed or collected. Some customers would like to track it closely.

Knowing the why, where and how factors mentioned above relates back to values mentioned earlier. People are motived by the invisible reasons and details. This detail allows householders to map their involvement back to their strong values. For example, for many it is comforting to know their energy needs are catered for first, before they consider sharing their excess energy; and then it is important to know they are sharing their excess energy. Additionally providing knowledge support consumer agency and consumer autonomy (mentioned earlier in section 5.3).

While it is important to understand what to communicate how and why, it is also important to know who will do the communicating, how, when and why. Details of whose responsibility it is to communicate were alluded to but not discussed in depth by participants in this project. Roles and responsibilities in communication relate back to our earlier social report on intermediaries [3] roles and responsibilities in relation to operating envelopes. Further work is needed to identify what organisations communicate what, when and why to consumers.

6. Discussion

Implications have been included in the findings sections within this report. Discussion of two key aspects of the report are expanded in this discussion section because their examination can assist with further development of SOEs. These two topics are SOE product features; and network and aggregator intermediary roles.

6.1 SOE features: features of a product, a product, or products?

SOEs as a concept and a product have value that overlaps with processes elsewhere. SOEs capture additional decision-making complexity than DOEs do, and this may prematurely foster a conclusion that SOEs are a logical "end point" for capacity management. The path from fixed to dynamic and ultimately shaped operating envelopes represents only one path through which capacity management approaches can be developed and may not be the only one. We suggest that an SOE as it currently is designed is not a finalised, immutable product which needs to be scaled (or dismissed) in its entirety. We argue that, from what we have heard from stakeholders, team members and consumers, SOEs can be assessed in terms of their constituent parts as all features were seen to have potential for multiple situations.

In Table 4 we have broken SOEs up into constituent 'parts' to highlight their multiple technical features and a range of both positive and negative elements as perceived by householders. This table is not comprehensive - it includes prominent examples for consideration. Examining these features helps us understand what SOEs offer to whom, and to open up our thinking about what SOEs might be able to achieve in the future, in what form, and the possibilities for scaling. Perhaps SOEs will be a standard feature of other products (eg aggregation services products), and thus completely hidden. Or perhaps the features can be applied in different ways. There could, for example be SOE related products that optimise for environmental impact or another value outside of cost. SOEs could also work differently with smaller or larger products, perhaps older or newer systems in different ways, and may also interact with different network infrastructure situations.

Table 4 Breaking apart SOEs (rows do not correlate)

What are the features and functions that constitute SOEs as they currently stand?	**What did householders perceive to be the positive elements of SOEs?**	**What did householders perceive to be the challenges of SOEs?**
Assessment of contributions of DER battery assets (currently) at different homes. DER battery assets are assessed on likely available extra	That SOEs ***could*** consider/factor in the householders' set ups better and were not just only considering network care.	SOEs were not fully comprehendible so householders couldn't see exactly what SOEs would do for them.

capacity, processed through aggregation algorithms. Is mediated through a cost lens and equations – so has a market. When in use for constraints on the network – balance power flows and/or hertz. Works within a set operating constraint already set by the network. Pays householders for their services (again, via aggregators algorithms) Connects at meter? Or battery? Or inverter? Or at a load?	That SOEs could incorporate householders' preferences or interests. That SOEs could reduce the amount of solar wasted (due to export curtailment). For some: the opportunity to make a community or environmental contribution through SOE participation. *For some:* the financial benefits. Improving the Return On Investment of their existing asset and a savings towards future maintenance/ replacement needs that they as householders would be responsible for.	Would SOEs include householder values and principles? Would an SOE introduce more complexity and burden on the householders? Would SOEs negatively impact self-consumption goals – reducing energy independence and ability of batteries to provide an energy back up during blackouts or brownouts. Would SOE participation introduce data privacy and hacking risks? Would they entail financial risks or uncertainties? What would an SOE mean in terms of control over one's asset? Perception that their own asset is being used to make profit for a business.

6.2 Network and Aggregator intermediary roles

If adopted in the future, SOEs may create or reinforce a relationship between aggregators and DNSPs. This means aggregators are an important intermediary in the uptake and operation of SOEs alongside networks. There are also other important intermediaries such as solar installers, early adopters, battery companies, consumer advocates, and regulators. The relationship between networks and aggregators in the instance of SOEs will have an extra layer of impact.

The SOE approach's main innovation over DOEs is that it adds aggregators as a formal role in capacity allocation processes, so available DER/CER related energy and services can be (more effectively) accessed. Aggregators are included as processors of SOEs as they are expected to be important intermediaries in DER owners' participation in DER/CER related energy markets through virtual power plants. Participants in our research appreciated the role of aggregators in managing DER/CER interactions with the grid on their behalf. In particular, longer-term DER owners appeared 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.

Although we can say that current aggregator customers were relatively comfortable with their relationship with their aggregator, they had specific feedback:

- They wanted better communication from their aggregators on how their devices were being operated; and
- They wanted to be sure aggregators were trustworthy, transparent, and responsive to their needs in how they managed competing interests and values.

Additionally, as observers we were aware that there are implications of SOEs in general and as applied through aggregation services. These are important to understand further both for CER owners involved and in relation to wider communities and social equity. Consumers were relatively comfortable with aggregation services as long as aggregators were responsible in how they participate in SOEs on behalf of their customers. From the feedback we received it is highly likely that SOEs may work well as a part of customer's relationship with their aggregator.

This suggests that if SOEs are scaled beyond the Converge trial, there is likely further understanding needed of how DNSPs and aggregators will work together. SOEs would form part of aggregator products they offer their customers but would affect network management.

7. Conclusions and what's next?

This report set out to relay rich findings from the social research from Project Converge. The social research sought to understand - via stakeholders, householders and the Converge design team - operating envelope evolution, responses to SOEs and related factors to consider for operating envelope application to DER/CER grid integration processes.

We found that while SOE features were supported by most stakeholders, there were caveats and further considerations called for. In this concluding section we provide summaries of areas where next steps could be taken, nested under five themes:

- Responding to values in technical design of SOEs;
- Pay mind to complexity;
- Implementation pathways need further exploration and definition;
- Supporting and defining the role of intermediaries; and,
- SOEs are a small part of a big picture for householders.

7.1 Responding to values in technical design of SOEs

Householders and stakeholders held values and principles they felt needed to underlie the development of grid integration solutions and operating envelopes into the future. The inclusion of self-consumption in the SOE engine is a demonstration of how values can influence the way technology is built and developed. In the case of SOE design, enabling self-consumption of energy first had some positive consequences for householders as self-consumption is generally highly valued by householders, particularly those with CER. However, this simultaneously limited the market benefits householders were able to obtain through their participation in an SOE, as well as the support able to be provided to networks.

Values associated with SOE technology were more diverse than the SOEs factored in. For example, as described in the technical report [32], equity was not explicitly considered in the SOE algorithm as built, but our participants strongly felt it should be. Principles and values also have implications for the broader system within which SOEs may operate. In terms of social equity, there was an expectation that the energy system be managed as a public good and that social implications of any new technology needed to be identified and responded to.

In addition to self-consumption and social equity, householders were heavily influenced by environmental values and affordability considerations. Value propositions of parties involved are worth examining in more depth. 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.

KEY TAKEAWAYS:
Values can and should influence the design of SOEs and how SOEs are implemented.
Values propositions of householders and stakeholders are worth examining in more depth to ensure the energy system is meeting citizens expectations and prevent values clashes (real or perceived) becoming a barrier to householder uptake of SOE products.

7.2 Pay mind to additional complexity and related actions

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 required of householders and stakeholders to engage in SOEs that they will need to be simplified or implemented in parts. SOE features can be considered individually if that is useful for the evolution of the application.

The complexity of the solution overall and of its application creates possible challenges for communications. Well prepared and curated communication is needed and can be an antidote for complexity in some ways. Stakeholders and householders involved do require understanding of key points and implications of engaging with DER grid integration solutions and operating envelopes. That grid integration and operating envelopes are on a maturity journey that affects application, including the ways we need to communicate, and the value being offered. Coordinated communication is needed and this will require multiple intermediaries to have input. Ensuring communication and engagement is well curated will assist to ensure implications are well understood and trust is in place on which to build a relationship for grid integration.

KEY TAKEAWAYS:
The decision to scale SOEs needs to be taken in the context of the additional complexity it creates. It may be that SOEs will need to be simplified or implemented in parts.
Well prepared and curated communication can be an antidote for complexity to some extent.

7.3 Implementation pathways for SOEs require further exploration and definition

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 (including opt in vs opt out and differences in renumeration agreements) with variations in approach having little apparent impact, likely in

part due to the solid relationship people had with aggregation services. The positives and negatives of both approaches will be useful to understand as part of value exchanges possible between householders and organisations and when considering the levels of mandatory and voluntary involvement with operating envelopes.

The Converge implementation of SOEs was quite different to the way DOEs have been applied elsewhere. SOEs were applied through existing aggregation processes and/or products and this ultimately effected the outputs for householders. This will require definition for future application. Commercial aspects were seen as having potential in relation to SOEs and we were advised that this avenue could be further explored in next steps. SOE features can be considered separately if that is useful in future development and implementation.

Additional factors were raised for consideration in the design of SOEs and the implementation model moving forward. These included: the broader contexts of householders; regularity of use of SOEs; who will SOEs apply to; influences on use of SOEs (e.g. constraints causing pressure to use envelopes); whether SOEs would be optional or mandatory; and whether householders would even notice SOE application.

KEY TAKEAWAYS:
SOEs appear to be best applied as a relationship between DNSPs and aggregators, however implementation details require further definition and testing.
SOE features can be considered separately if that is useful in future development and implementation.

7.4 Supporting and defining the role of intermediaries

Intermediaries are clearly important for the scaling of SOEs. The role of aggregators was explored in detail in this research. Customers of aggregators we spoke to were generally relatively comfortable with their relationship with their aggregator (although they did have specific feedback on communication), suggesting that existing aggregator relationships are stable enough to offer great possibility for integrating operating envelopes moving forward.

On the other hand, both householders and stakeholders raised concerns about how aggregators would manage competing interests. What responsibilities aggregators should actually carry in the SOE relationship were interrogated, finding that it is likely that aggregators cannot be an impartial agent for householder values other than financial. We question whether it was reasonable to expect aggregators to cover this role.

While the role of aggregators has been explicitly considered to date, understanding how other intermediaries relate and interact with operating envelopes and with consumers will need further consideration as SOEs are developed. Installers were identified as an additional key intermediary (alongside aggregators) in this instance. Aggregator and network relationships were seen as needing further understanding moving forward.

Stakeholders identified the need for crucial industry roles and responsibilities around consumer care and communications to be clearly defined. Stakeholders are seeking coordination around communications and support for consumers in relation to evolving operating envelope technologies and solutions, as they are with other grid integration technologies. Who will independently observe effects on behalf of consumers need to be understood, and this may include having multiple organisations working together.

KEY TAKEAWAYS:
Existing aggregator relationships offer great possibility for integrating operating envelopes moving forward however it seems unlikely that aggregators themselves will be able to incorporate householder values beyond financial.

Other intermediary roles require further definition, including clarifying roles around consumer protections and coordinating communications to consumers.

7.5 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 EV. This means communication with householders need to be framed within this context. Other factors including householders' current energy management practices and related energy efficiency measures, also need to be considered in operating envelope and grid integration solutions moving forward.

Householders do make decisions about CER and grid integration based on a wide set of values and principles, and involvement is not just about finances. Social equity for their communities and environmental impacts are factored into their assessment of how to act with the grid. These motivators and principles need to be considered as operating envelopes are evolved.

Householders thinking about taking part with SOEs required more information to be comfortable with their decision to take part, process how grid integration and operating envelopes might align with their values, consider perceived trustworthiness of organisations involved, consider whether they wanted to engage with another organisation, assess the effort involved, seek out understanding of security and safety, and more.

KEY TAKEAWAYS:
Householders are likely to consider SOEs within the larger context of CER products and services and energy management practices. Householders want more information about the implications of participating in an SOE, including how it aligns with their values and the effort it entails.

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Appendices

Appendix A - Definitions and acronyms

ACT – Australian Capital Territory

AEMO – Australian Energy Market operator

AER - Australian Energy Regulator

ARENA – Australian Renewable Energy Agency

CER – Consumer Energy Resources

DEIP - Distributed Energy Integration Program

DER – Distributed Energy Resources refer to assets or systems that generate or store renewable energy from separate, distributed locations. They can be located on private, commercial or public property. DER includes solar generation at homes, electric vehicles and batteries. Further explanation can be found at Distributed energy resources - Australian Renewable Energy Agency (ARENA) .

DNSP – Distributed network service providers

DOE –Dynamic operating envelopes are electricity import and export limits that vary over time and location. DOEs can enable higher levels of energy exports from customers' solar and battery systems by allowing higher export limits when there is more hosting capacity on the local network.' (Dynamic Operating Envelopes Workstream - Australian Renewable Energy Agency (ARENA))

DSO – Distribution systems operators/operations

FOE – Fixed operating envelopes set limits on the import and export of electricity. Networks have used FOEs in the past and largely continue to use them today to ensure electricity levels in the grid do not breach thermal or voltage limits. They are static and account for 'worst case scenario' conditions.

Grid Integration –Grid integration is the process of incorporating electricity generation into an existing system. This includes connecting what are often called consumer energy resources, like household batteries, into the local electricity network. Integration with the grid leads to householders being in a two-way relationship with the grid.

HEMs - Home energy management systems

Intermediaries - Human actors who have a function or purpose in any given system, and as such are key actors of the system. Intermediaries can act as catalysts for change. The social research for this project uses the concepts of intermediaries as developed through transitions and innovation research, where intermediaries are seen as brokers and catalysts who can have a

range of functions in any system or innovation niche (for example Kivimaa et al 2018). Intermediaries are recognised as those who play a key role in whether or not a niche technology becomes mainstreamed (or part of the regime) (Özden-Schilling, 2023).

NMI – National Meter Identifier. A number that identifies a specific meter on networks/grids in Australia.

OE – Operating envelopes are a term used to note the limits that an electricity customer can import and export to the electricity grid. These limits are most likely set by networks but are likely agreed between networks, customers and the Australian Energy Regulator as part of the customer connection or regulatory process. Currently, in most cases, operating envelopes are fixed at conservative levels regardless of the capacity of the network because they are static and need to account for 'worst case scenario' conditions.

SNM – Strategic Niche Management

Socio-technical – Approaches of investigation and theories that incorporate consideration of social and technical factors.

SOE - Shaped operating envelope

VPP - Virtual power plants - are clusters of energy sources working together via coordination platforms and systems, to provide energy supply (most often to an electricity network). They can include multiple (and many) energy sources and do not need to have energy sources located together. These varied energy sources are often called DER. –VPPs provide a way to connect lots of distributed energy resources together so they can bid together into energy markets.

Appendix B - Methods – further detail

In this Appendix we provide further detail on the stakeholder and householder interviews and workshops described in the Methods section of this report. For each group of interviews and workshops (listed below in chronological order) we have included a brief outline of our interview and workshop approaches, lists of our guiding questions as well as links to slides and a recording of a presentation given to householder workshop participants.

Stakeholder interviews

Stakeholder research interviews were conducted during the last quarter of 2022. All interviews were semi-structured, and participants were encouraged to discuss what they thought was important as experts in the areas. The list below covers the questions that were planned. These topics were generally mostly covered in each interview. Exploration was the key here, so the concepts and vicinity of conversation was important, rather than people specifically answering a particular question. The interview steps and questions were:

- Some explanation was provided of SOEs to begin with.
- Asked to briefly note a little of background and sorts of roles related to [DOEs, SOEs].
- Asked is role/position supported development of innovative or niche solutions for the electricity industry or electricity market.
- Then establishing whether familiar with key concepts – VPPs, DER, DOEs. Shared any definitions needed.
- Asked about use of other names for DOEs.
- Relayed operating envelope background (as needed), the talked about Project Converge and asked is SOEs were familiar.
- Explained SOEs if needed. Also provided a background document before appointment describing DOES, SOEs and a little background as to why they were being developed.
- Sought any initial comments on anything mentioned.
- Asked about DOE implementation and critical contexts. Including about DOEs in implementation and scaling, opinions on current DOE application, and any egs they may know of, opportunities and challenges, and anything needing to be in place for DOE success.
- Asked about and SOE implementation and critical contexts. Including seeking insights into SOEs in general and whether SOEs have a place in the current and near-future 2-way energy sharing electricity systems, where they may be useful, the critical things that need be in place to ensure SOEs work in commercial or applied settings at scale.
- Asked about DOE and SOE similarities and differences.
- Asked about what alternative and complimentary strategies there are to both DOEs and SOEs.
- Asked about electricity industry stakeholder needs and expectations that need to be considered before, and as, DOEs and SOEs are applied.
- Asked about energy users and their experience/anticipated experience as DOEs and/or SOEs are implemented.
- Asked about key assumptions DOE and SOE solutions make about end users.
- Asked about how communities and community-based collectives might get involved somehow with DOEs and SOEs.

- Asked about what would need to be in place to ensure DOEs and SOEs are applied in a fair and reasonable way (for organisations and users alike).
- Asked about examples of where energy users/consumer/prosumers are currently involved in the design or checking of application of DOEs.
- Asked about anything to add in relation to concepts like energy justice, distributional justice, energy equity or and responsible innovation?
- Asked about organisational roles and perspectives in relation to DOEs and SOEs. Including whether there are new roles and activities needed.
- Checked if there were any other insights they would like to share.

Householder Interviews

All householder interviews were semi-structured, and participants were encouraged to discuss what they thought was important and most critical to contribute. The list below covers the questions that were planned. These topics were generally mostly covered in each interview. Exploration was the key here, so the concepts and vicinity of conversation was important, rather than people specifically answering a particular question. The interview steps and questions were:

Section 1: Customer/distributed energy resources – what sorts, how long, how purchased

1. We were interested to know what distributed/consumer energy resources you have and roughly how long you have had those? In particular battery, Solar panels and electric vehicles?
2. Do you recall what motivated you to get your solar panels, battery or EVs? Has your motive for having these changed since installation?
3. Were you part of the Next Gen Energy Storage (battery rebate) Program in Canberra, or did you buy your battery through another channel?
4. We are interested to understand briefly if the battery was affordable for you, or a bit of a financial risk? We are not asking about incomes with this project, but generally we contextualise findings with some understanding of how difficult purchasing a technology might be. So we are just keen to get a feel for this broadly.
5. This is a stepped questions about getting involved with converge.
    a. Did you end up taking part in the Converge technical trial?
    b. We are interested to understand why you are taking part/not taking part.
    c. What do you think of the process that was used to recruit participants? Did this approach work ok for you and/or do you have any comments about this?

Section 2: Background information provided to householder

[Interviewer outlined energy system changes and challenges regarding capacity management and DER/CER integration as well as operating envelopes as a possible part of the solution. Refer to Appendix C for more detail about the information shared.]

Section 3: Opinions about background, capacity management and DER/CER grid integration

6. Now I have shared something of the energy challenges or opportunities just now.
    a. Do you have any comments about anything I have just mentioned?

    b. Was any of this familiar to you?
7. Do you have any comments on the congestion and management/capacity issues networks face in relation to electricity supply?
    a. Do you think any of what I explained is important to understand as a householder who is involved in a VPP?
    b. What are your first impressions of the solution being tested? *Note we will talk more about this later.*
8. Have you any thoughts about aggregator roles in this solution?
9. As a longer-term owner of a battery, is there anything that you think about differently now compared to when you first owned a battery? This might be in relation to how you expect to use it or how you think about it integrating with the grid. Your perspective being a longer-term battery owner is of interest to us.

Section 4: Opinions about DOEs and SOEs

10. From what I have mentioned about dynamic and shaped operating envelopes:
    a. Do you have any comments to make about using operating envelopes as part of how we might manage congestion and electricity management issues on networks?
    b. What do you think might happen if this approach was adopted throughout Australia?
11. [For those taking part in the Converge testing] Were you aware that shaped operating envelopes had been applied/tested?
12. We understand that there have been trials and tests afoot, but we suspect this might not be that noticeable, so we wanted to check. Have you noticed anything different in the way in terms of how your aggregators systems interact with your battery?
13. A new part of this solution is that aggregators are able to be more involved and influence how much export allocation can come from each consumer battery. In this trial I think there is a default for this. This approach is different from previous solutions where possible energy export opportunities from batteries were assigned without this Aggregator information. This is said to make assignment more nuanced and as energy exports and import controls can be assigned to those who need it and/or where it might be available.
    a. Any comments about this aggregator role or the principles for allocating exports?
    b. Do you have any thoughts on what would be a reasonable way to allocate energy exports for operating envelopes?
    c. Who do you feel are the right people/organizations to set the principles for how energy exports and energy controls are allocated?
14. Is there anything you think dynamic and shaped operating envelope solutions assume about households?

Section 5: Householder perspectives about DER/CER and its use in network integration solutions

15. What do you feel the role of DER/CER could or should be on the grid, when it is connected? What is reasonable to ask of DER/CER in relation to the grid and managing capacity on the grid, or when you are sharing energy with the grid?
16. What principles or values might be important in relation to the grid and managing capacity on the grid, or when you are sharing energy with the grid?

17. Being connected to an energy network that at times connects to your devices / appliances / assets to manage congestion or create better energy flows can mean organizations (the network for eg) need to connect and control your assets. I have some questions about this:
    a. What level of control might you be happy with a network or aggregator having and when would this be ok by you?
    b. If there was a spectrum of control options where one end was hand over complete control to hand over no control – where would you probably sit?
    c. What devices do you think it is ok to connect to?
    d. How does your battery connect with [your aggregator] now?
18. Do you think householders might like to participate in design decisions around potential VPPs or other network solutions? What form could this involvement take?
19. From your experience with a VPP and thinking about having consumer energy resources connected to various grid management solutions:
    a. What effort do you think is ok and/or feasible for householders to dedicate to interacting with VPPs or other grid connected activities?
    b. What has being a VPP participant meant day to day for you up to this point? Is there much time required?
    c. What kind of level of support would you like and expect, and in what form?
    d. What kind of support have you had in the past?

Section 5: The role of financial considerations - tariffs and incentives, including compared to other values

20. Do you have any comments to make about financial considerations? Including tariffs, incentives, or payments for grid support (services) your devices provide?
21. What approach does [your aggregator] use to payments for providing grid support through your batteries? And do you have any comments to make related to these?
22. Is it worth it to have your battery involved in a VPP? Why? Why not?
23. Does the financial side of things motivate you to be involved, compared to other values and motives you might hold?
24. Do you think there should be financial benefits to contributing your assets for grid integration purposes?

Householder workshops

All householder workshops were semi-structured, and participants were encouraged to discuss what they thought was important and most critical to contribute. The list below covers the questions that were planned. These topics were mostly covered in each workshop. Exploration was the key here, so the concepts and vicinity of conversation was important, rather than people specifically answering a particular question. Workshop participants were presented background information on the energy system and operating envelopes at two points during the workshop. Presentation slides, speaking notes and recording can be accessed at: https://bsgip.com/research/converge/ or through the following links:

- Presentation for workshop – slides and audio
- Presentation for workshop – PDF
- Speaking notes for workshop presentation – PDF

The workshop steps and questions are outlined below.

Presentation of background Part 1 - constraints and DER

The first group of questions explores your view on the electricity network and its role. We want to understand how you your thoughts on capacity in the context of the electricity networks and your perspectives on the way the capacity of the network could impact your day-to-day life.

Before we jump into questions, can I please see by a raise of hand who has:

- Solar
- A battery
- An EV?

Question 1: What are your initial responses to this first presentation?

Further related questions:

- What is your understanding of the issues facing electricity networks – this can be at the local scale or more broadly about Australia?
- Have you any comments to make about pressures on electricity supplies or network capacity?
- Are there any implications you thought about (for you or for others) / that you can immediately see from the electricity system changes?

Question 2: Networks are attempting to avoid expanding their networks by asking consumers to change how they consume energy, perhaps altering times of use, or turning off devices at certain times. In some cases technology might be used to automate this change in consumption patterns. What do you think about the various approaches including consumers and potentially consumer devices?

Further related questions:

- Would you be willing to change anything in your day-to-day energy use to help avoid adding further poles and wires and/or to manage network capacity?
- What sort of actions do you think you could take?
- What would prevent you making changes to your day-to-day energy use (to help manage network capacity)?
- What would you require in return from networks (and other organisations involved) to make changes (to help manage network congestion)?
- What mechanisms could networks (and other organisations involved) adopt that would help you help them?
- What is the role of technology, including solar, batteries and electric vehicles in enabling these changes?
- What would the impact of some people being asked to change behaviour much more often that others be?

Question 3: What should be considered as the electricity system, including networks determines how much to invest in a bigger network versus how much to ask consumers to

change behaviours, or to integrate their own devices with the grid (consumer energy resources)?

Further related questions:

- What principles should the electricity system, including networks, adopt when deciding on approaches to use?
- What should networks consider in relation to consumers and their situations?
- What shouldn't networks consider?
- What are the values that you would like to see reflected in the way that consumer energy resources/devices are integrated into the energy system?
- Can you see barriers for yourself or others in getting involved?

Presentation of background Part 2: FOE, DOE, SOE

Question 4: What are your initial thoughts after hearing about operating envelopes in this 2nd presentation?

Further related questions:

- Do these approaches make sense?
- What are the benefits of this approach from your perspective?
- What are the disadvantages of these approaches from your perspective?
- Which approaches do you like more or less and why?

Question 5: Are they approaches you would consider participating in? Why or why not?

Further related questions:

- How do these approaches align with (or not align with) with your values and expectations?
- What do you feel networks should be aware of when considering adopting these methods?

This last question explores the concepts of capacity allocation when consumers take part in the grid via their energy devices (batteries, solar, electric vehicles etc). Grid involvement can be through aggregators and virtual power plants, or through more direct agreements with retailers or networks. Networks need to make decisions around how they allocate capacity. And it is likely other electricity system organisations, such as aggregators, will also be involved in allocation decisions.

There are a few key factors to consider:

- Different parts of the network have different levels of constraint which means some people may get less energy supply and energy export than others.
- There may be consumers who are located in a part of the network where it is especially useful for them to alter their consumption/generation therefore they may be asked to do it more often that others.

- There may or may not be remuneration/financial compensation/incentives depending on the sort of support a consumer's energy device provides.
- Aggregators are quite involved and have the ability to make decisions that influence allocation of capacity in their virtual power plants based on availability.

Question 6: What do you feel is a reasonable way to assign capacity in the shaped operating approach?

- What is important to consider in assigning capacity? Are there values or principles that could be applied?
- What would the impact of some people being asked to change behaviour much more often that others be?
- Who should get to decide what in relation to allocating or assigning capacity?
- What would be the most reasonable way to assign capacity?
- Do consumers simply help out with maintaining the operating envelopes or do you think financial benefits are needed? And why?

Stakeholder workshop

In the second stakeholder workshop (February 2024) participants were presented early findings from the householder interviews and workshops woven in with the technical trial findings. The key emerging insights shared were:

Self-consumption was a major value for participants but drastically reduced grid benefit.

- Participants wanted to see more information (e.g. how their support was used)
- Large participation requirements mean SOEs need to have widespread interest to create grid benefits.

The research team then facilitated a discussion prompted by the following questions:

Question 1 - Have you any initial thoughts in response to Laura's presentation?

Question 2 - Values came through in consumer data as clearly important in relation to participation. Self-consumption, which we heard about in the presentation, is a major value for participants. We also heard from people about helping out the local network for the benefit of their community, of sharing excess and about caring for the environment by electrifying (doing their bit to electrify and get off other fuels), for example. Financial viability was there too among a list of really inspiring values.

So, self-consumption is a significant value/motivator for PV and battery owners. Yet, as we heard in the presentation, self-consumption could drastically reduce grid benefits from SOEs. And indeed we have seen this tension before in other trials – self consumption allows people to be comfortable with grid integration but does affect the grid integration processes.

We are interested to hear any thoughts you have about any of these interconnected issues.

Prompt - Do the networks have an obligation to notify/inform/engage customers about how they are using their DER?

Question 3 – We are keen to layer in concepts of scaling of DOEs and SOEs into the discussion now. Scaling is important for all new technology. SOEs at scale can be used to better support network capacity management. However, SOEs can only maintain the network within its secure limits if enough controllable distributed energy is available when needed. Another factor is that it is likely that lots of the DER involved will come from householders.

So for it and other technologies that are grid integrated to work, we need enough people to get involved. But we know we are likely to also have intention/values/motivations clashes as operating envelope technologies like SOEs scale. And, we also noted how self-consumption when built into algorithms, will take out significant network support effects that could otherwise be achieved.

Have you any comments on scaling?

Question 4 - Large participation requirements mean SOEs need to have widespread interest to create grid benefits.

DOEs, grid integration, and SOEs are all complicated. Adding network support and markets to householders' existing energy use processes adds to what householders and consumers need to understand about DER. Integrating concepts of how DER interact for networks and market services can take a bit of learning.

Participants wanted to see more information (e.g. how their support was used). We are aware from this and previous trials that we need to communicate specifically and deliberately about critical issues; we need to impart complex knowledge; we need to let people know how their DER are being used; and when. In essence, we need to make sure they are aware of the who, what, when, and why – these all need to be shared.

Appendix C - SOE explanations provided to participants

We described SOEs and aspects of context to participants before discussions were conducted, because of SOEs being a new concept and many related concepts being less commonly known. The way we described SOEs will have impacted how participants responded in our research and how they think about the new technology (SOEs) introduced. In stakeholder interviews DOEs and SOEs were described and then discussion developed around their responses to these descriptions. The main aspects of our explanations in consultations with householders focused on explanations of the trends creating pressures on network, the concerns about capacity management and then the progression of operating envelope solutions. Descriptions of topics covered with householders and stakeholders are described in Methods (Section 2.2) and in Appendix B. We provide further insight here in relation to how we introduced operating envelopes to provide readers with some understanding of how the concepts were introduced. Additionally, the steps used here are useful to further explain what SOEs are doing.

To introduce SOEs, we first introduced operating envelopes and used the terms fixed, dynamic, and shaped operating envelopes (FOE, DOE, SOE respectively) to explain the progression to more complex operating envelopes. We used a stepped description using scenarios as shown in Figure 2, Figure 3, and Figure 4 below. Our descriptions were necessarily simplified due to limited time with participants (normally 1 hour for interviews or 1.5 hours for group conversations). For the full presentation, please see the online recorded version of the workshop introduction at https://bsgip.com/research/converge/ .

There likely would not have been a way to describe the technology that did not have some impact on how the technology was thought of by participants. Implications of our descriptions and the importance of words was described by several participants and forms part of our "communication" findings described in Section 5.3.

Fixed operating envelopes

We relayed fixed operating envelopes (FOEs) as the more static envelopes that have been used by networks when they do not have more real time, dynamic assessments. These are currently often called static operating envelopes and they tend to anticipate for longer periods of time and set an operating envelope with no real time system attached.

We described FOEs by providing an example highlighting how fixed envelopes could limit the connection of devices to the energy system, in this case solar PV. In this example, the 10kW capacity of the network is managed by allowing connection of PV systems up to 2.5kW per consumer. This allows each to generate up to their full capacity at all times while not overloading the network.

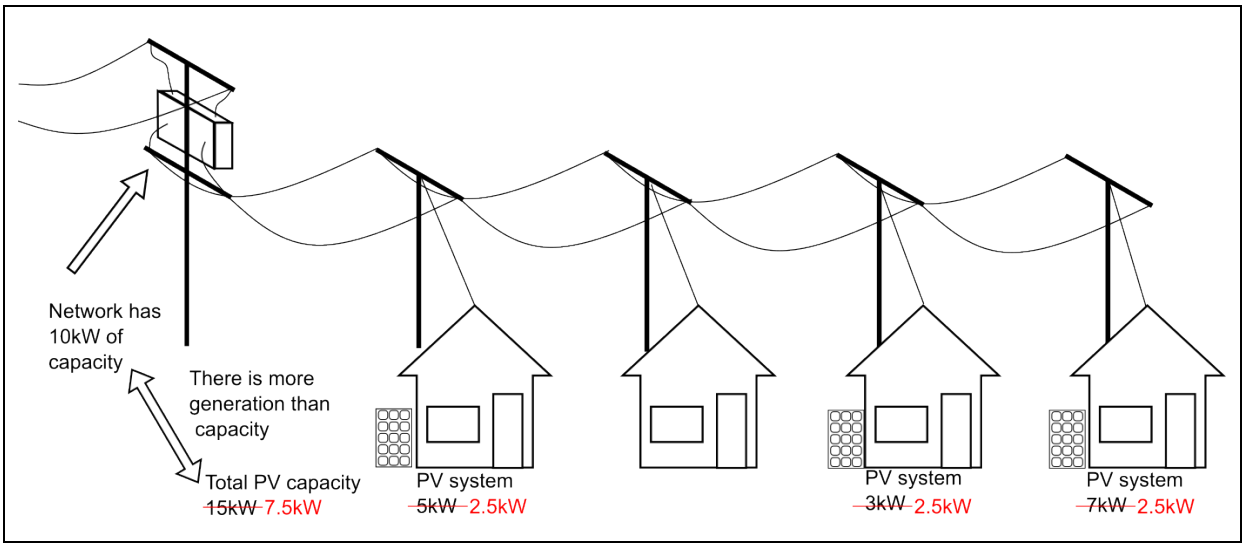

Figure 6 Example of a fixed operating envelope (FOE)

Dynamic operating envelopes

Dynamic operating envelopes were described as per standard and existing definitions. The example of a DOE provided showed the assessment undertaken to determine how much PV can be connected to capture real-time factors. This enables excess capacity that is apparent in real-time to be used. For example, in this case the capacity that would have been allocated to the consumer without PV is distributed across the currently installed PV systems. We also discussed that there are many ways capacity could be allocated in this approach, aligning with the SOE design implementation report's assertion that *"there is not just one way to allocate envelopes while ensuring that network limits are met; rather, there is an uncountable number of ways"* [2]. In particular the method we chose to illustrate here results in a lower capacity allocation for the consumer with the smallest PV system than they would have under FOE.

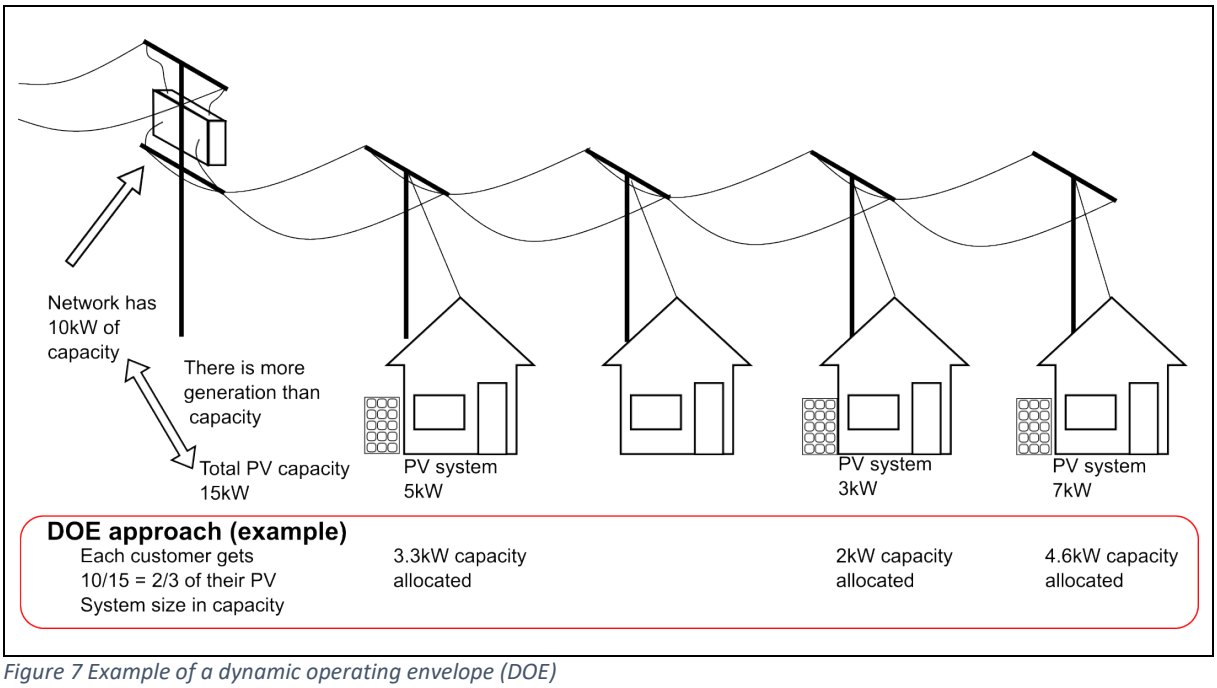

Figure 7 Example of a dynamic operating envelope (DOE)

Shaped operating envelopes

We built upon the DOE definition to propose shaped operating envelopes as adding a step before the DOE calculation where consumer preferences were collected.

In the case of SOEs we described photovoltaic preferences being requested capacity and a price. In contrast to DOEs, we discussed this approach as allowing for capacity to be assigned in a way that maximises usage (e.g. people don't get capacity they don't need) and cost (e.g. the cheapest capacity is used). In our description we also discussed the need for an agent (e.g. an aggregator) to express these preferences in real time.

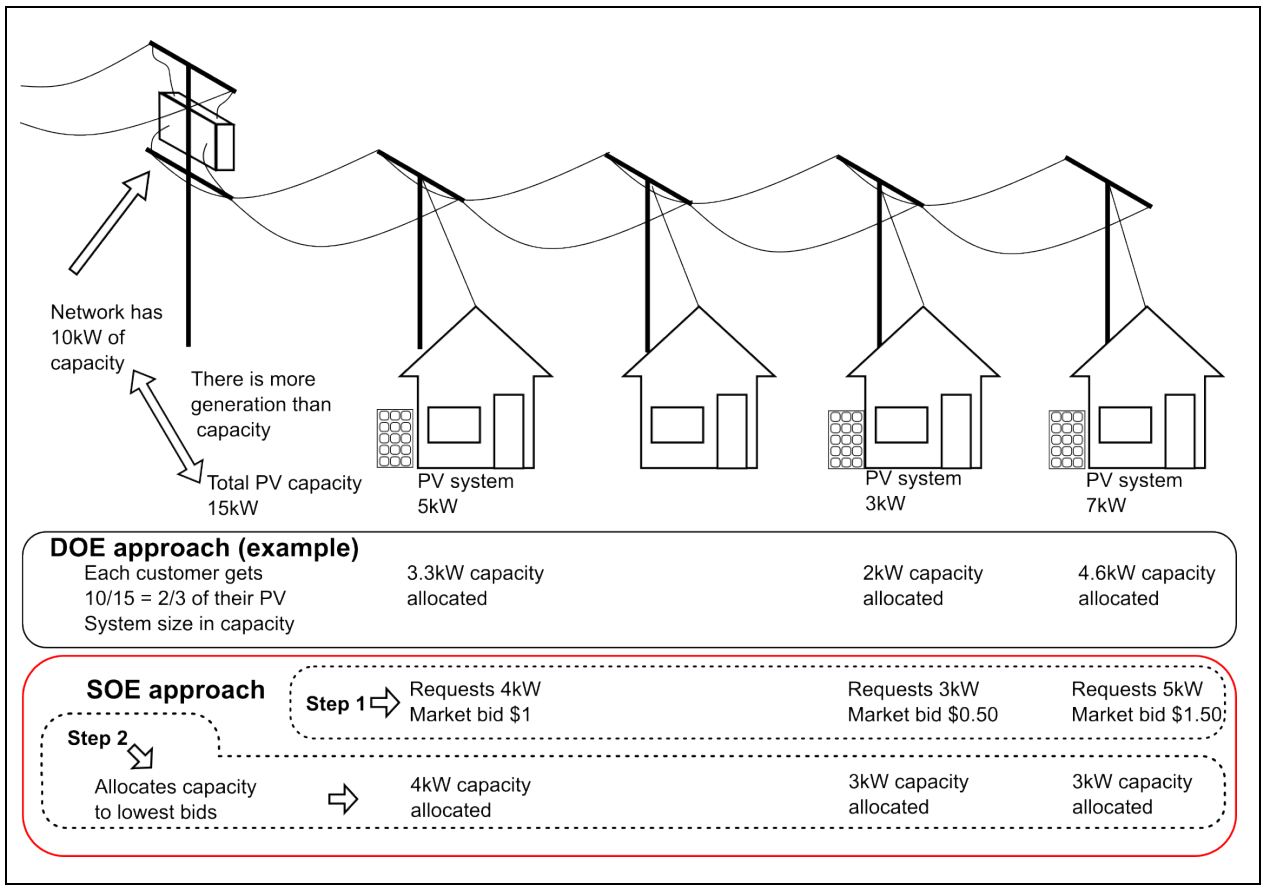

Figure 8 Shaped operating envelopes

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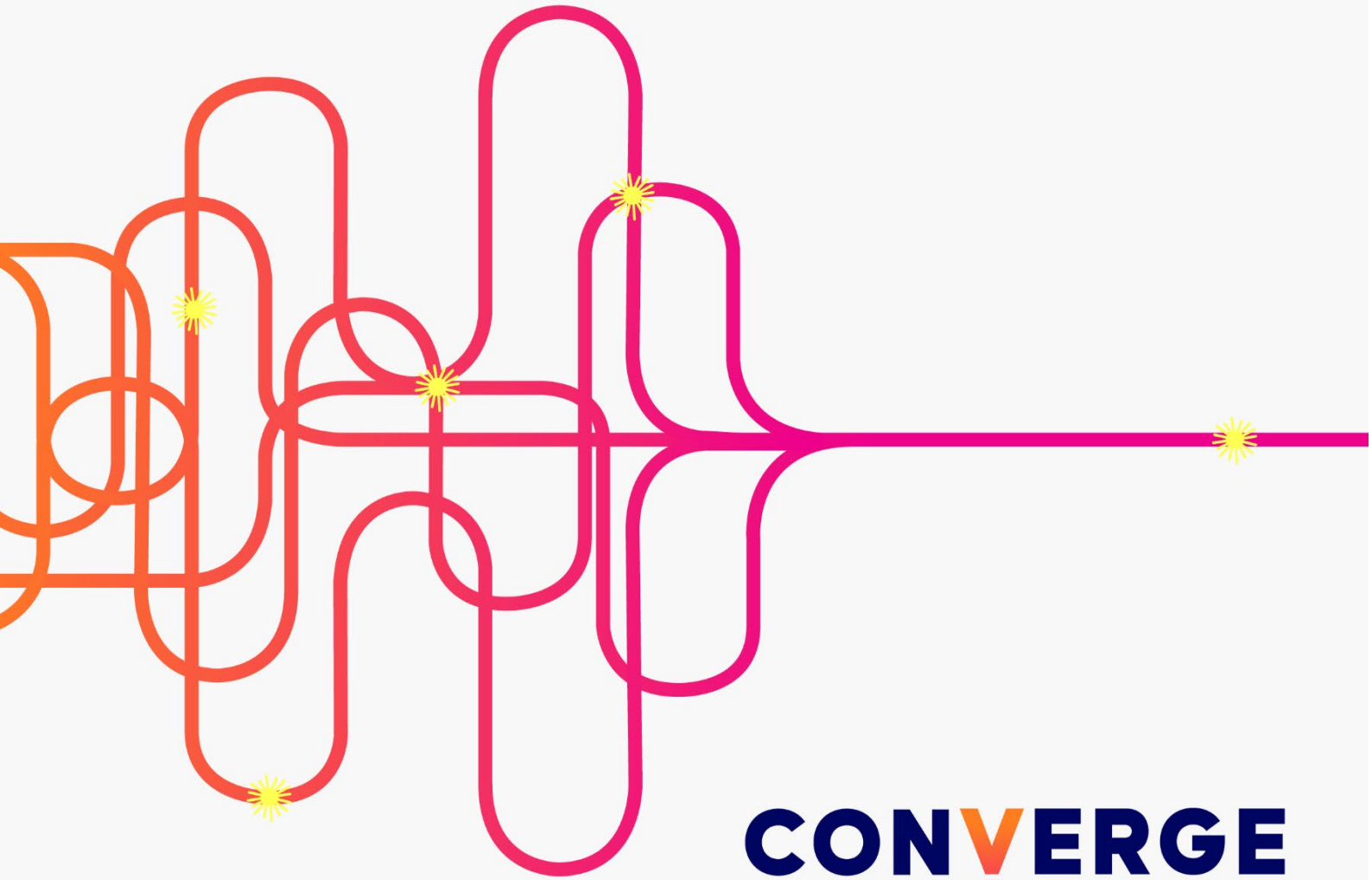

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