Flexible Exports for solar PV

Final trial report

19/10/2023 – version 1.3

SA Power Networks

AusNet services

switchDin

Fronius

SMA

solaredge

Purpose

This document is the final Knowledge Sharing Report for the Flexible Exports for Solar PV Project. This public report describes the project, activities undertaken, outcomes achieved, and lessons learned.

Disclaimer

This Project received funding from Australian Renewable Energy Agency (ARENA) as part of ARENA's Advancing Renewables Program. The views expressed herein are not necessarily the views of the Australian Government, and the Australian Government does not accept responsibility for any information or advice contained herein.

Acknowledgement

The "Flexible Exports for Solar PV" project ('the Project') is a collaboration between SA Power Networks, AusNet, Fronius, SMA, Solar Edge and SwitchDin.

The Australian Government, through the Australian Renewable Energy Agency (ARENA), is providing $2.09m towards this $4.84m project under its Advancing Renewables Program.

Project overview

The project planning began in July 2020, with live operations commencing in September 2021. The project formally concluded in March 2023, although the systems remain in operation. The project has been led by SA Power Networks, in collaboration with AusNet, Fronius, SMA, Solar Edge and SwitchDin. Any parties interested in discussing the contents of this report directly with SA Power Networks are encouraged to contact James Brown, Strategy Lead – DER Integration, at james.brown@sapowernetworks.com.au.

Further information on related ARENA trials can be found on the ARENA website.

Executive summary

Australia is rapidly adopting PV systems with more than 290,000 each year within the National Electricity Market (NEM). These systems offer tremendous benefits by serving as a zero-cost source of energy, displacing traditional generation methods, and reducing CO2 emissions. However, the widespread use of solar PV poses challenges for Distribution Network Service Providers (DNSPs). The distribution network was designed for varying peak demands, but solar panels often export power concurrently during daytime hours, impacting safety and network stability for all customers. To safeguard network integrity, DNSPs set static export limits at customer connections. These static export limits, reduce customer benefits and the supply of clean, renewable energy to the market.

To alleviate this, SA Power Networks, AusNet, SwitchDin, Fronius, SMA and SolarEdge collaborated to develop, and trial, a new Flexible Exports customer connection offer for solar PV customers who would otherwise be subject to zero or near-zero export limits. This new option enabled these customers to export energy to the network most of the time, with exports only limited during the few specific periods when the network is constrained. This enabled trial customers to get significantly more value from their solar PV system and release the substantial economic and environmental benefits of solar PV exports to the wider community.

At the beginning of the trial, project partners and broader industry recognised that a nationally agreed communications interface was critical to efficiently integrating CER with distribution networks across the country. Key early work for this project was to develop a draft specification for an Australian version of the Common Smart Inverter Profile (CSIP) IEEE 2030.5 implementation guide that had been developed for the Californian market. The project successfully delivered a draft to the national DER API Technical Working Group (DERAPITWG) in 2021, which how now been converted into a Standards Australia handbook (SA HB 218 CSIP-AUS) and is being used to support Flexible Exports rollouts in South Australia, Victoria, and Queensland.

New technology was developed by all partners to support the Flexible Exports connection option. SwitchDin developed a modular IEEE 2030.5 CSIP-AUS compliant utility server that was used by SA Power Networks and AusNet to communicate flexible export limits to customer sites. This Utility Server was modular by design to provide other DNSPs fast path to market at trial completion.

Additionally, both SA Power Networks and AusNet developed new operational systems to calculate and publish flexible export limits. Both DNSPs integrated with SwitchDin's modular utility server via common interface, demonstrating the portability of the solution. Changes to the DNSP installer facing systems and/or processes were also made to enable Flexible Exports to be offered.

SwitchDin and Fronius modified their existing customer technology to support CSIP-AUS, enabling participation in the trial. The SwitchDin solution leveraged the Droplet, a small gateway device that enabled non-compatible solar inverters to work with the Flexible Exports. Fronius built a cloud-based integration that enabled their Gen24 range of inverters to participate with no additional hardware required on site. These solutions were the first two CSIP-AUS capable technologies on the market.

The field trial was launched on 23rd September 2021 and concluded on 30 June 2023, with the following offers from SA Power Networks and AusNet Services:

	SA Power Networks	AusNet
Existing export limit arrangements **(CER SEG <30kVA)**	5kW per phase export limit, regardless of network location.	Automatic assessment for export limit between 0kW-5kW per phase, depending on available local hosting capacity.
New Flexible Exports offer	Flexible export limit that varies from 1.5-10kW per phase Fixed export of 15kW/phase	Single phase (non-SWER) customers with existing zero export/reduced export may join the 12-month trial to receive up to 5kW Flexible Export.
Eligibility	Available in selected congested zone substation areas.	Customers with <3kW export. Includes: Existing 'retrofit' customers with a compatible inverter + internet. New customers choosing a compatible inverter + internet.

Key insights on customer experience, technology solution, network benefits and solar industry gained in the project are summarised below:

Customer experience

- Customers accepted Flexible Exports and understood the reasons for the introduction, preferred this to a fixed option and majority would recommend to family and friends.
- Higher satisfaction was experienced by customers who understood the offering and their installation prior to installation.
- Participating customers got access to higher export limits compared to alternative fixed export options

Technology solution

- CSIP-AUS can be successfully leveraged to enable a Flexible Exports connection option across multiple network regions.
- Operational systems were robust and available data from the trial has provided confidence when preparing for business-as-usual operations.
- The adoption of a nationally consistent framework into the future will assist the OEMs in technology development and provide OEMs with technical and financial certainty, leading to scalability of the connection offering.

Network benefits

- DNSPs can provide much greater export access through a Flexible Exports option compared to a fixed exports.
- Significant network capacity is unlocked for use through the operation of Flexible Exports
    - In South Australia, on average devices received export limits at 10kW or their system capacity for 99.4% of the time.
    - In Victoria, an additional 154.62MWh of energy was unlocked for participating trial customers.

Solar industry

- Installers understood the Flexible Exports option and were able to install and commission Flexible Exports equipment.
- Limited compatible equipment availability impacted the ability for many solar retailers to offer Flexible Exports to their customers. This has been resolved by new regulations in South Australia with more than 95% of equipment by market share being Flexible Exports capable. Uptake of the offer in SA has jumped from 36% choosing the flexible option during the trial, to more than 85% choosing the flexible option in the BAU rollout. New requirements coming to effect in Victoria in 2024 may have the same impact.
- Installation and commissioning of Flexible Exports capable equipment is an additional step in the solar installation process and will require good training materials and support to succeed at scale.

Following the successful completion of the trial, SA Power Networks commenced the rollout of Flexible Exports as a standard connection option from 1 July 2023. The introduction of the offer coincides with new SA Government regulations that mean all new and upgrade installations in South Australia must be capable of participating in Flexible Exports. The rollout is occurring suburb by suburb with the offer expected to be available statewide from 1 July 2024. Beyond the rollout, SA Power Networks is turning its attention to the integration of Flexible Exports with retail offers in the ARENA funded Market Active Solar Trial, and exploring how other flexible assets such as EVs, battery storage and smart loads can participate in flexible connections.

AusNet are continuing to offer the Flexible Exports option to the customers who participated in the trial, while planning for the next phase of implementation, which will be led by state and policy decisions. Key upcoming changes in Victoria include CSIP-AUS capability as a mandatory requirement for the Victorian Solar Homes rebate from 1 March 2024, and DEECA's recommendation for CSIP-AUS to be utilised for Victoria's solar backstop mechanism from 1 July 2024.

The Flexible Exports for solar PV trial represents a crucial milestone in advancing solar energy integration and grid optimisation. The insights gathered from the field trial provide invaluable knowledge, guiding the way for a more sustainable and efficient energy future. The success of this project paves the path for a national adoption of flexible export limits which will result in significant benefits for distribution networks, customers, and the Nation's broader decarbonisation targets.

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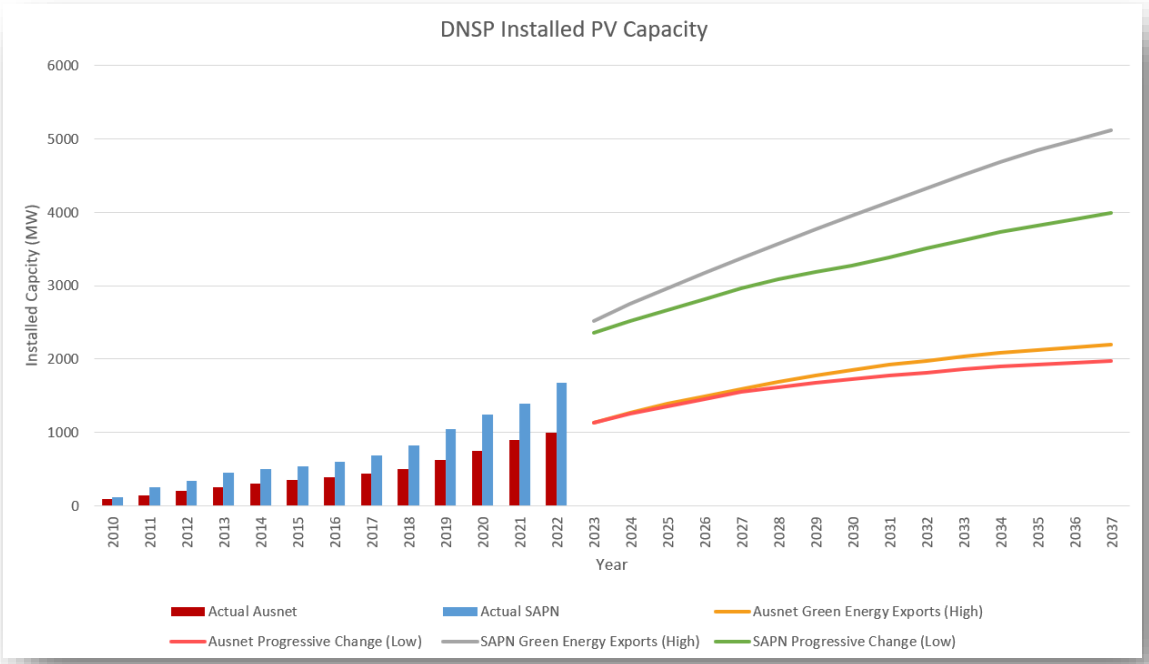
1 Introduction

1.1 Project context and overview

Australians are currently installing new PV systems at a rate of more than 290,000 per annum across the National Electricity Market (NEM). These systems provide great benefit to the electricity system as a whole, acting as a zero marginal cost source of generation and offsetting CO2 emissions by displacing traditional forms of generation.

Figure 1: Historic solar PV installed capacity and forecast uptake for SA Power Networks and AusNet[1]



The increasing uptake and proliferation of solar PV presents challenges for Distribution Network Service Providers (DNSPs), as the distribution network has a finite physical capacity to accommodate PV systems while maintaining safety, quality, and security of supply.

The network was designed to cope with peak demands that naturally vary due to the diversity of customer usage patterns, however rooftop PV output lacks this diversity. All rooftop PV systems in the same local area are generally exporting at full power simultaneously in the middle of the day, and creates issues around safety, quality, and security of supply for the network.

This is illustrated in Figure 2 which shows how solar output in the middle of the day can exceed the afternoon peak demand for which the network was designed.

1 Forecasting data from https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp/2022-isp-inputs-assumptions-and-scenarios

Figure 2: Network demand - Salisbury trial aggregated load from Solar PV customers

To protect the integrity of the network for all customers, networks must consider the worst-case reverse power flow (typically occurring on mild, sunny days in spring), and set static export limits at each connection point to ensure this doesn't exceed available network capacity. Historically, these limits have been set at 5-10kW per customer across DNSPs but, even with these limits in place, the physical limits of the network are now being reached. This has led some networks, such as Victorian DNSP AusNet, to impose zero and reduced export limits to customers connecting new solar PV systems to constrained parts of the network. SA Power Networks' modelling showed that such action would be required in South Australia soon.

These export limits are set at the time of customer connection and persist for the life of the PV system, causing customers to lose out on a large portion of the benefit of their investment. In addition to directly impacting individual solar PV customers, limiting exports reduces the amount of low cost, clean, renewable energy available to the market, which means greater reliance on traditional fossil-fuel generators. This leads to higher costs for all customers as the wholesale market price remains higher on average than it would be if solar were not curtailed, as well as higher CO2 emissions.

Nationally, there is significant regulatory and policy reform underway to unlock more value from DER through the deployment of Flexible Exports. The SA Government has now mandated[2] flexible export capability for all new solar installations from 1 July 2023. Furthermore, the Victorian government has made Flexible Exports a mandatory capability for Solar Homes rebate eligibility from 1 March 2024. The ultimate roll-out of Flexible Exports nationally will be dependent on DNSP led initiatives or future policy decisions. The Flexible Exports trial has been extremely valuable in informing responses to policy reviews and evidence gained throughout the trial has positioned AusNet and SA Power Networks as influential voices in the national discussion.

2 The Flexible Exports for solar PV project

2.1 Project objectives

The project aimed to accelerate the development of an Australian standards-based approach to flexible feed-in management for solar PV across the NEM. To achieve this, the project scope was designed to advance both the technical and commercial maturity of the next generation of smart

1. https://www.energymining.sa.gov.au/industry/modern-energy/solar-batteries-and-smarter-homes/regulatory-changes-for-smarter-homes/dynamic-export-limits-requirement

inverters and develop the customer offer and customer experience of participating in a Flexible Exports scheme.

At the beginning of the project the key outcomes and deliverables for the project were defined as:

- In consultation with customers and industry, develop a new Flexible Exports connection offer for solar PV customers who would have otherwise been subject to static export limits
- Address the key issue of customer understanding and acceptance of the proposed new connections services, build social license, and explore the customer experience of this approach in operation. Inform Australia's DNSPs and the broader industry of the most effective, equitable and customer-friendly way to introduce this kind of flexible connection option as a new standard for DER customers, including:
    - The kind of information customers need to understand and engage with this kind of connection agreement, and the best channels to convey this information
    - The level of education required for the solar industry and installer community
    - The customer experience as their system operates automatically under the flexible export limit through all seasons, including times when the system is unconstrained and times when export limits are reduced. This includes how this experience compares to customers who accept a static zero- or reduced-export arrangement, and the kind of data, reports, and information that customers value in understanding the performance of their solar PV system.
- Quantify and prove the value unlocked for trial customers who would otherwise have been subject to zero or near-zero export limits, providing an evidence base for DNSP investment in enabling this service for the AER
- Provide the first practical end-to-end demonstration in Australia of flexible feed-in management for individual solar PV customers who may not be part of a VPP or aggregation scheme
- Develop a draft communications standard for communicating flexible export limits to smart inverters to support national and international adoption.
- Accelerate the development of the technical capability for Flexible Exports management in the three market-leading inverter manufacturers' products plus many more inverter brands through the SwitchDin gateway to enable the widespread adoption of this new offer as a standard network service across the NEM post-trial
- Develop a reference implementation of an IEEE 2030.5:2018 utility server developed by partner technology company SwitchDin ready for adoption by other DNSPs post-trial.

2.2 Customer offers overview

SA Power Networks and AusNet developed customer offerings for Small (residential) customers who install PV systems with generating capacity <30kVA. These offers have been summarised in Table 1. The offers differ between DNSPs due to the customer cohorts being targeted, differences in network configuration and technology approach.

Table 1: Summary comparison of Flexible Exports offers

	SA Power Networks	AusNet
Existing export limit arrangements (DER SEG <30kVA)	Automatic approval for 1.5 or 5kW per phase export limit, regardless of network location.	Automatic assessment for export limit between 0kW-5kW per phase, depending on available local hosting capacity.
New Flexible Exports offer	All new and upgrading customers in eligible areas have a choice between Flexible Exports (1.5-10kW limit per phase) or reduced fixed 1.5kW limit per phase.	Single phase (non-SWER) customers with existing zero export/reduced export may join the 12-month trial to receive up to 5kW Flexible Export.
Eligibility	Available in selected congested zone substation areas. Customers must install a compatible equipment and have an internet connection.	Customers with <3kW export. Includes: Existing 'retrofit' customers with a compatible inverter + internet. New customers choosing a compatible inverter + internet.
Approach	All inverter manufacturers, retailers, and installers able to participate. Customers offered Flexible Exports for the life of their installation or revert to 5kW in the event Flexible Exports is not continued beyond the trial.	Offered as a 12-month trial. AusNet recruited eligible 'Retrofit' customers to the trial. New installations with restricted export limits encouraged to submit an EOI (expression of interest).

2.2.1 SA Power Networks

SA Power Networks trial development was led by a broader implementation strategy for delivering Flexible Exports as a standard service offering. The trial was designed as a mirror to the model of the proposed broader rollout to ensure the learnings would be as applicable as possible.

Hosting capacity modelling conducted as part of the SA Power Networks LV Management Strategy found that, in the long run, current distribution network assets can accommodate 1.5kW of export per customer on average under fixed export limit arrangements. Thus, the 5kW fixed export limit that has applied historically is no longer sustainable.

To mitigate this, SA Power Networks introduced the following two connection options for customers connected to selected constrained zone substation areas:

- Fixed export limit of 1.5kW/phase

- Flexible export limit that varies 1.5-10kW/phase

The fixed export option was included to provide customer choice for those who did not want opt in to the Flexible Exports trial.

It was anticipated that Flexible Exports customers would get access to 10kW export limits for 98% of the time during the 12-month field trial.

The offer was initially available to customers connected to Sheidow Park zone substation and was later expanded to include Blackwood, Blackpool, and Mitcham zone substations. The suburbs where the offer was available are shown in Table 2.

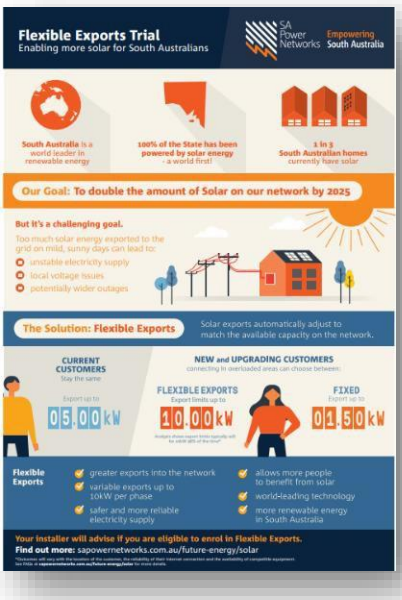
Table 2 List of Flexible Exports trial eligible suburbs

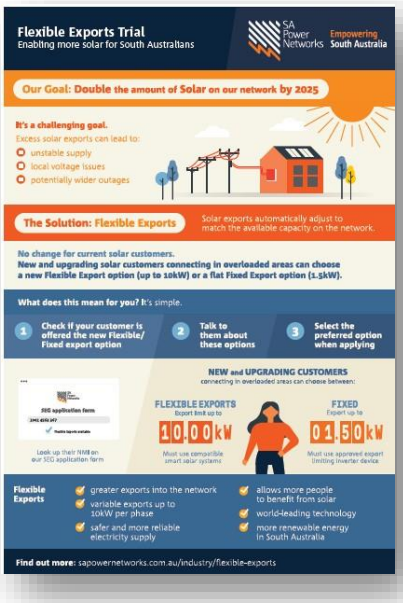
Belair	Glenelg South	North Brighton	Seacombe Gardens
Bellevue Heights	Glengowrie	North Haven	Sheidow Park
Blackwood	Hallett Cove	Oaklands Park	Somerton Park
Brighton	Happy Valley	O'Halloran Hill	Taperoo
Coromandel East	Hawthorndene	Old Reynella	Torrens Island
Coromandel Valley	Hove	Osborne	Trott Park
Craigburn Farm	Largs North	Outer Harbor	Warradale
Dover Gardens	Marion	Park Holme	
Eden Hills	Mitchel Park	Reynella	
Glenalta	Morphettville	Reynella East	

**Note only partial availability within some suburbs as substation boundaries do not line up nicely with suburb boundaries.

To further simulate post-trial conditions, the Flexible Exports option was open to all solar retailers and installers. As these organisations are the main point of customer contact for solar sales, SA Power Networks initial approach was to enable them to be a conduit through which Flexible Exports is offered. SA power Networks created communications artefacts for both installers and customers to use in the solar sales process, including dedicated web pages, infographics, videos, and training courses.

Figure 3: Infographics for Customer (left) and installer (right)[3]





[3] For higher resolution versions of the customer (https://www.sapowernetworks.com.au/public/download/?id=324009) and installer (https://www.sapowernetworks.com.au/public/download/?id=324010) infographic

Two training courses, each worth 30 continued professional development (CPD) points for accredited installers[4], were offered to solar installers by SA Power Networks and hosted by the Clean Energy Council. One course provided information on what installers needed to know about Flexible Exports and the other focused on ensuring systems installations are compliant.

Industry information was made available on the SA Power Networks site page Flexible Exports*[1], and customer information was delivered through a video link*[2].

A key principle of the offer is that technology and installations should be industry-led, rather than dictated by SA Power Networks. This means all hardware, such as compatible solar inverters, import/export meters, gateway devices (e.g., SwitchDin Droplets) are owned by the customer. As a result, for the majority of the trial, where SwitchDin Droplets were required, there was a small additional cost to participate compared to the 1.5kW fixed export limit.

Establishment and maintenance of device internet connection is also led by installers and customers. Any flexible export system will fall back to the 1.5kW export limit in the event of a communication outage, which incentivises customers to utilise reliable internet connectivity to maximise their ability to export. There is a trade-off between a simple, no-cost Wi-Fi connection to the inverter, compared to hardwiring the system to the home internet connection or establishing a dedicated 4G/5G connection at additional cost.

2.2.2 AusNet

In Victoria, the offer was open to customers who received a constrained fixed export limit through the connection assessment process and was therefore not targeted to specific areas of the network.

AusNet have an existing automatic assessment process for embedded generation applications ≤10kW per phase in capacity. The assessment process results in a fixed export limit generated for the customer of 0kW-5kW per phase depending on the hosting capacity available on the customer's substation.

AusNet created two customer offers, including a retrofit option targeted to customers who were already on a zero or reduced export limit and who had compatible inverters and eligible connections. The customer offer would provide up to 5kW flexible export:

1. A retrofit option for customers who have already installed a compatible inverter and have been assigned a fixed export limit of <3kW
2. An opt-in offer for new solar customers who receive a fixed export offer of <3kW

These customers' PV inverters were fitted with a SwitchDin gateway device to enable the Flexible Exports capability. The Flexible Exports offer was not available for customers in network regions supplied by SWER networks.

Retrofit customers were identified from the AusNet DER Register, their trial eligibility was assessed, and a direct offer was sent to these customers. New customers were made aware of the trial as part of the online application tool and then recruited through an expression of interest on the AusNet website. There was also a campaign to work with installers to find both new and retrofit customers, however, there was a low uptake from installers.

As well as requiring customers to have a compatible inverter and constrained static export limit, AusNet had to validate all customers' eligibility to participate in the trial by performing an assessment for each individual site based on network data. This was a two-step manual assessment.

[4] Solar installers are required to accumulate 100 CPD points per annum to maintain their CEC accreditation.

*[1] https://www.sapowernetworks.com.au/industry/flexible-exports/
*[2] https://www.youtube.com/watch?v=X_2ioBuNbVI&feature=youtu.be

2.3 Technology overview

The technology delivered in this project builds upon previous Dynamic Operating Envelope (DOE) and DER integration trials conducted by SA Power Networks and AusNet. For SA Power Networks, the project directly leveraged the core systems stack developed in the Advanced VPP grid integration trial where SA Power Networks and Tesla successfully deployed the systems and capabilities to support issuing of a dynamic export limit to the Tesla VPP. The AusNet Flexible Export trial architecture leveraged the Distributed Energy Resource Management System (DERMS) developed by Mondo (AusNet's commercial energy business) through projects including the Yackandanda Community Minigrid Project, DEECA Microgrid Trial and the Deakin Minigrid project.

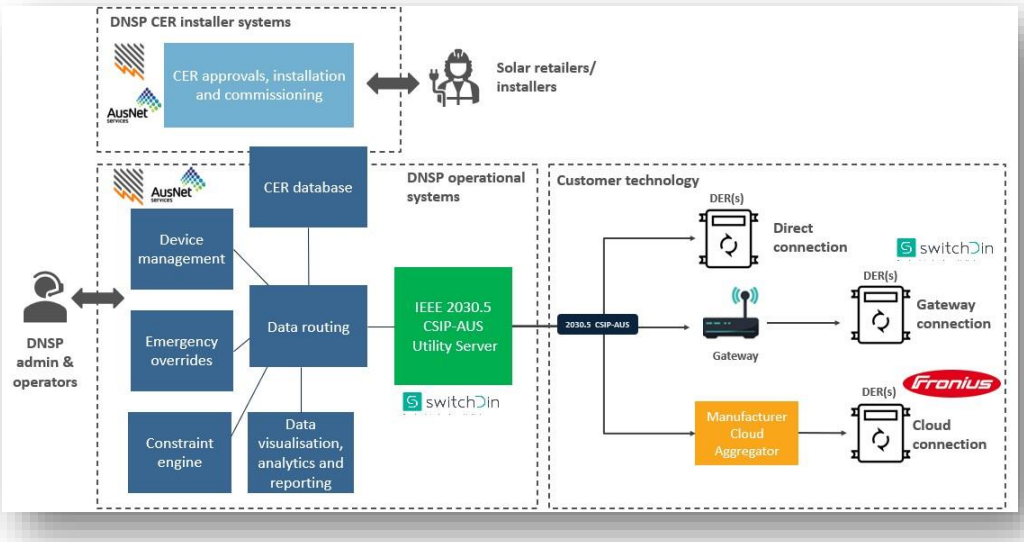
Efforts in the Advanced VPP project, Australian National University's (ANU) evolve DER Project along with a broader industry recognition for the need for a common Consumer Energy Resource (CER) integration communication protocol, led to the establishment of the DER API Technical Working Group (API working group). In conjunction with the API working group, this project developed and demonstrated a standards-based approach to DER integration using international standard IEEE 2030.5, ultimately resulting in the development and publication of the Common Smart Inverter Profile Australia (CSIP-AUS) which has recently been turned into a Standards Australia handbook (SA-HB 218:2023[5]).

The system capabilities were built to enable four key use cases that were foundational to providing a Flexible Exports connection option:

1. Device registration
2. Calculating, publication and enactment of flexible export limits
3. Export limit override in emergency situations (such as minimum system load events)
4. Visibility of connected CER and behaviours

Figure 4 shows the high-level systems architecture that enabled these use cases in the trial.

Figure 4: Flexible Exports Trial systems landscape



Below is a summary for the core system components built in the project: customer technology, DNSP operational systems and DNSP CER installer systems.

[5] SA HB 2018:2023 is available for no cost at https://www.standards.org.au/standards-catalogue/standard-details?designation=sa-hb-218-2023

Customer technology:

- IEEE 2030.5 CSIP-AUS supports 3 integration models:
  - Direct connection where the inverter has inbuilt support for receiving flexible limits via CSIP-AUS
  - Gateway connection where a separate physical device translates the CSIP-AUS flexible export limit messages and manages inverters onsite
  - Cloud connection where a manufacturer or third-party cloud aggregator receives the flexible limits via CSIP-AUS and translates and communicates these to inverters using non-standardised protocols
- SwitchDin modified their Droplet gateway device to support CSIP-AUS communications for a range of different inverter series.
- Fronius modified their partially developed IEEE 2030.5 aggregator which was initially designed to meet California's Rule 21 requirements.

DNSP operational systems:

- SwitchDin developed a modular, standards compliant IEEE 2030.5 CSIP-AUS Utility Server which acted as a 'plug and play' translation box between a DNSPs backend operational systems and CSIP-AUS compliant CER.
- SA Power Networks and AusNet built or enhanced their backend systems to support the trial, including:
  - Constraints Engine to calculate flexible export limits based on real-time network conditions
  - Emergency override capability for system emergencies
  - DER database and device management capability to support registration
  - Visibility, analytics, and reporting capability to monitor CER and system performance

DNSP CER installer systems

- SA Power Networks developed new CER approvals capabilities to support solar retailers and installers with the new option.
- AusNet leveraged their existing approvals process, as well as a separate EOI manual assessments process to provide the offer.

More detail on the systems implementation can be found in Section 2 Technology system design.

2.4 Timeline

Planning for the Flexible Export trial began in 2020. The field trial began in September 2021 and findings are based on the trial period ending in May 2023. All trial customers remain or will be offered the opportunity to remain on the Flexible Exports offer following the trial.

The timeline for the Flexible Export trial and beyond is shown in Figure 5. The three phases of the project are summarised below:

- During phase one, trial development, we worked with industry to develop plans and capabilities to support the Flexible Exports trial launch.
- During phase two, field trial of Flexible Exports, testing the end-to-end service was conducted to prove value. This report will consider the findings during these first two phases.

- The third phase consists of the scale up to business-as-usual offerings which both SA Power Networks and AusNet are currently operating and refining. These will be discussed in the Future work section of this report.

Figure 5: Flexible Export and Industry timeline

2.5 Report structure

The remainder of this report is structured as follows:

- Section 2 describes the technology system design
- Section 3 describes the way in which the field trial was conducted
- Section 4 explains the insights and learnings gained from the trial
- Section 5 describes the vision and plans for future work

3 Technology system design

This section will explore the approach to CSIP-AUS development and the 3 building blocks of the system architecture introduced in Section 1.2.3.

3.1 CSIP-AUS development and evolution

A key objective of the trial was to develop and test an standards-based approach to communicating flexible export limits between DNSP systems and DER systems from multiple manufacturers. Such an approach could enable rapid adoption of Flexible Exports in other jurisdictions and minimise effort and rework for equipment manufacturers in ensuring their products are compatible.

Consultation with industry in the lead up to the Advanced VPP Grid Integration trial found that IEEE 2030.5 Common Smart Inverter Profile (CSIP), already mandatory in California, was the most appropriate starting point for Australia. SA Power Networks developed a simplified API specification modelled on CSIP to test with the Tesla VPP in that trial.

In parallel to this trial, the cross functional DER API Technical Working Group[6] was formed to facilitate the development of a national DER communications specification. Through discussions and learnings from initial trials, it was determined that a full IEEE 2030.5 compliant interface was necessary to ensure national interoperability. The need for an active trial to demonstrate this capability was the genesis of the Flexible Exports for Solar PV trial.

Within the project, AusNet, SA Power Networks, SwitchDin, Fronius, SMA and SolarEdge collaborated to develop a draft IEEE 2030.5 implementation guide based on the CSIP guide used in California. Key modifications from core CSIP include the recognition of site-level export limits instead of direct to device controls to better reflect the DNSP to customer relationship in the Australian regulatory context. An initial version, dubbed Australian Smart Inverter Profile (ASIP) was developed to support the trial.

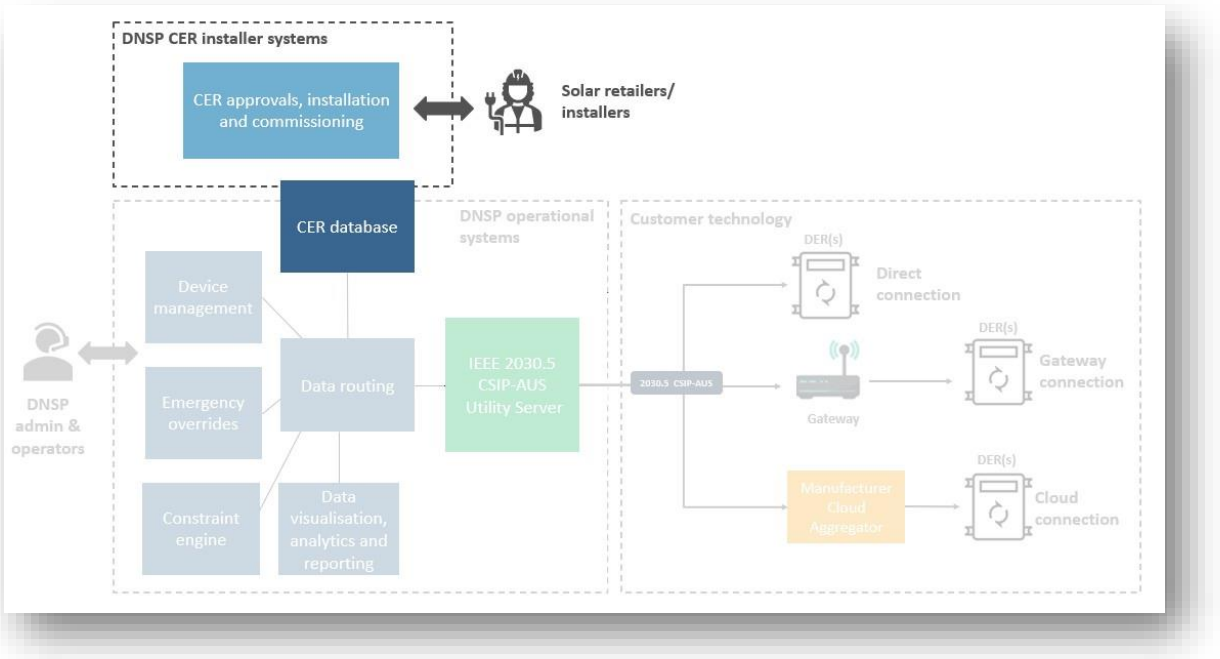
The ASIP was also provided to the API working group who commenced extensive review and ultimately drafted and published the Common Smart Inverter Profile – Australia (CSIP-AUS Version 1.0) in 2021. CSIP-AUS has now been published as a Standards Australia Handbook.

3.2 DNSP CER installer systems

DNSP CER installer systems facilitate the network connection approval and closeout for CER installations. In this process, DNSPs typically collect information about an installation and set rules and guidelines around inverter settings and export limits. Both SA Power Networks and AusNet implemented changes to systems or process to facilitate the enrolment of customers in the trial.

[6] The DERAPITWG includes representatives from AEMO, DNSPs, solar equipment manufacturers, energy retailers and aggregators.

Figure 6 DNSP CER installer systems



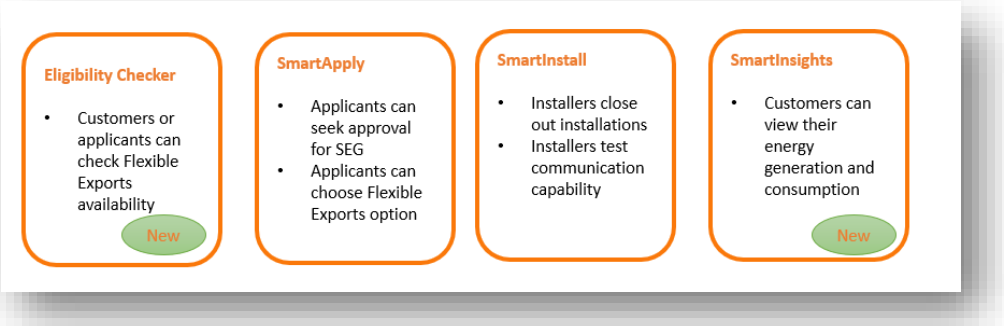
3.2.1 SA Power Networks

SA Power Networks developed new solar application and closeout portals as part of a broader strategy to collect better information on installations, improve compliance and enable smart CER connections like Flexible Exports. Two new portals were launched in June 2021:

- **SmartApply connection applications portal:** this portal collects information about a connection application and provides instant approval for installations compliant with SA Power Networks connection rules.
- **SmartInstall connection closeout portal:** Collects information about what was installed and configured and is intended to be completed by the installer while onsite.

The shift to Flexible Exports necessitated a process that transitioned from only administering connection application approvals, to one that manages the end-to-end lifecycle of a DER network connection. Significant changes were made to SA Power Networks' systems and process to accommodate this which can be seen in Figure 7.

Figure 7: Systems added or adapted to accommodate Flexible Exports



The following sections describe the changes made to accommodate each step in the lifecycle.

3.2.1.1 Eligibility checker

The eligibility checker enabled customers or their solar retailer to determine whether they were in one of the congested substation areas eligible for Flexible Exports. The page contains links to other relevant SA Power Networks web pages which provide greater detail on the fixed and flexible options.

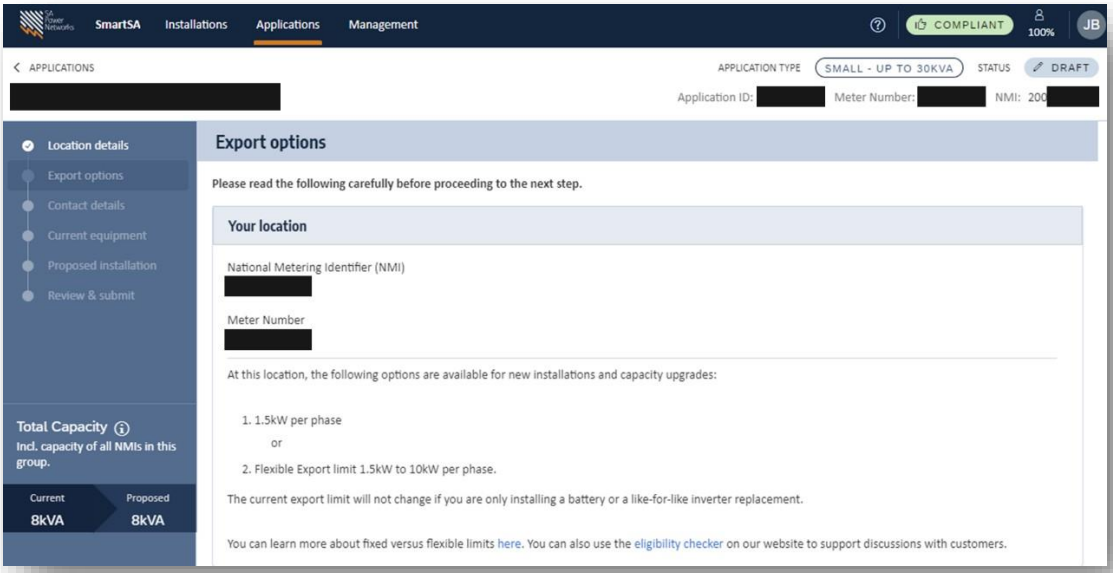
Figure 8: Eligibility checker

3.2.1.2 SmartApply application portal

The SmartApply portal underwent numerous changes to support the trial Flexible Exports offer, including:

- Validating and presenting the flexible and 1.5kW fixed export options for customers within eligible substation areas.
- Ensure the appropriate compatible equipment is available for selection when the Flexible Exports option is selected
- Enable the submission and instant automatic assessment and approval of a Flexible Export application

Figure 9: SmartApply options information page

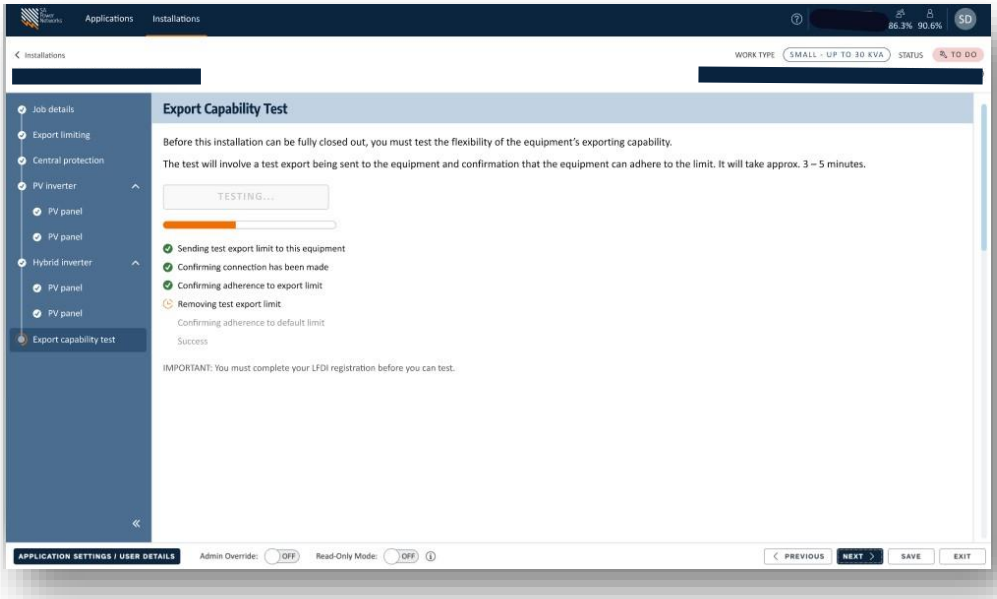


3.2.1.3 SmartInstall closeout portal

Our existing portal, SmartInstall, which is used by installers to close out installations, was adapted to accommodate Flexible Exports application, including capture of all equipment required to facilitate the Flexible Exports option.

A key learning from the trial was that installers needed to have greater visibility from the DNSP systems as to whether a site has been registered and is operating correctly before they leave site. To that end, SA Power Networks developed the capability test which runs through a short routine and validates correct registration, communications, and adherence to flexible export limits. This change should greatly assist with minimising any repeat site visits due to setup or commissioning issues.

Figure 10 SmartInstall capability test



3.2.1.4 SmartInsights customer visibility platform

SmartInsights was developed during the trial to provide customers with visibility of their flexible export limits and solar performance. The platform was rolled out to a small number of customers during the trial to elicit feedback and improvements. Based on the positive feedback, SmartInsights will be further developed and rolled out as part of the post-trial Flexible Exports connection option.

3.2.2 AusNet

AusNet has an existing online application portal which gives many customers an immediate assessment of their available connection offer based on the hosting capacity of their local distribution network infrastructure. The online tool was updated with a banner during the trial's active recruitment phase to direct applicants to submit a Flexible Exports expression of interest if they received a static export offer of less than 3kW export limit.

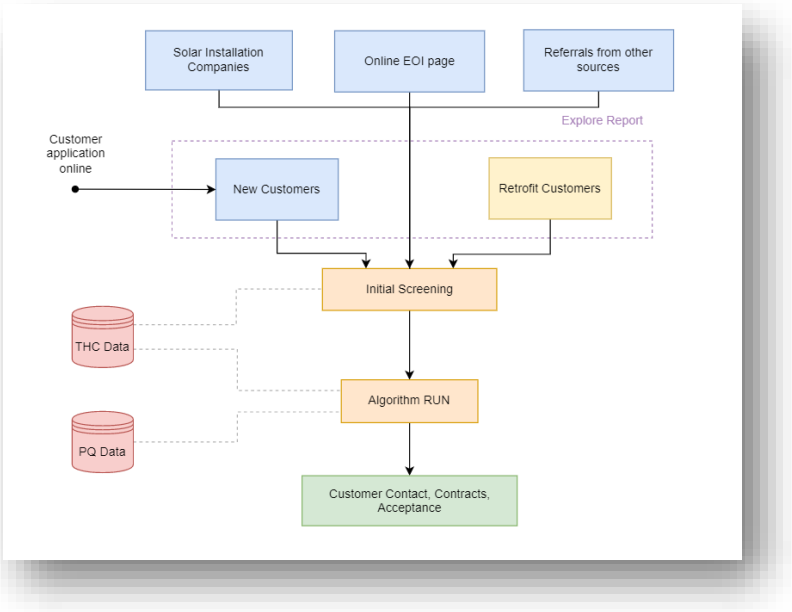
For customers that submitted an expression of interest, a subsequent eligibility assessment was required by the Flexible Exports trial team, which was a two-step manual assessment process, comprising the following steps:

1. Confirming customer equipment compatibility and the Tactical Hosting Capacity (THC) of the customers local distribution substation
2. Engineer's assessment of customer PQ data in relation to the Flexible Exports operating envelope algorithm

Because these processes were unable to be automated as part of the trial (the PQ assessment was done by a real engineer to validate the algorithm), we could not integrate Flexible Exports eligibility assessment into our automated application portal. However, our existing portal that is used to submit applications for embedded generation already had the capacity to immediately validate the available capacity of substation and notify customers of an export constraint, which was then the catalyst for the customer submitting an expression of interest for the Flexible Exports trial.

Figure 11 shows the overall process of the manual assessment for Flexible Exports.

Figure 11: AusNet Manual assessment process



3.3 DNSP Operational Systems

DNSP operational systems implement the four core system use-cases of the Flexible Exports service:

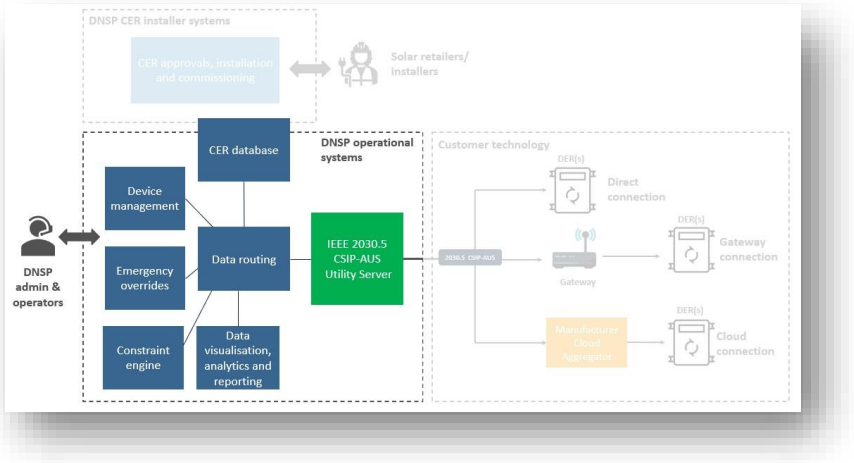
- Device registration

3.4 Calculation and publication of flexible export limits

3.5 Emergency overrides

- Network visibility, compliance monitoring and reporting

Figure 12 Flexible Exports trial DNSP operational systems



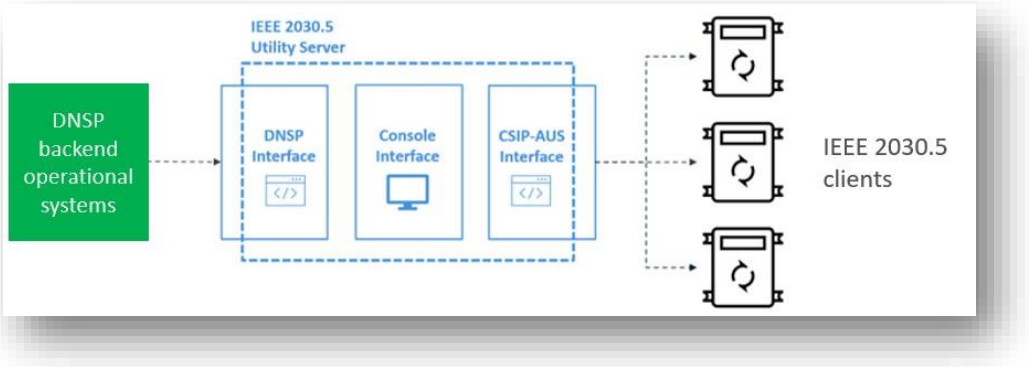
This section explores the approach taken by SA Power Networks and AusNet to support the trial.

3.5.1 Utility Server

Based on their existing experience with IEEE 2030.5 CSIP through the Horizon Power's Onslow Microgrid project, SwitchDin were selected to develop the Utility Server for the project. The Server was designed to be a modular component in the DNSPs CER integration architecture to enable rapid adoption by other DNSPs post-trial. Another advantage of this modular approach is that DNSPs can design their backend systems to be protocol agnostic and integrate additional modular protocol converters as the DER landscape evolves.

The functional design of the utility server was codeveloped by SwitchDin, AusNet and SA Power Networks with the aim to ensure the implementation was common across both DNSPs. To achieve this, the design was split into 3 core components shown in Figure 13.

Figure 13 Utility Server high level components



In the figure:

- **CSIP-AUS interface:** This interface was developed to implement the latest version of CSIP-AUS as co-designed by the project and API Working Group. It enables standards-based communication with direct, gateway and cloud-based clients that can be 'plug-and-play' between jurisdictions.
- **DNSP interface:** This interface enables communication between the Utility Server and the DNSPs backend operational systems. It was designed to be common across SA Power Networks and AusNet implementations to ensure the design is as portable as possible.
- **Console interface:** This web-based user interface enables DNSP administrators to set various configuration parameters, view communications logs and access the server's internal database.

SwitchDin's utility server development and delivery were highly collaborative, integration with DNSP systems were occurring in parallel to ensure the product met the needs of both DNSPs.

3.5.2 SA Power Networks

3.5.2.1 Operational Systems build

SA Power Networks operational systems directly leveraged the capabilities built in the Advanced VPP Grid Integration trial. The same agile DevOps team was responsible for modifying and enhancing these systems to support integration with the Utility Server and meet the needs of the Flexible Exports service offering. Systems are deployed on SA Power Networks Microsoft Azure Tenancy and largely leverage PaaS based microservices.

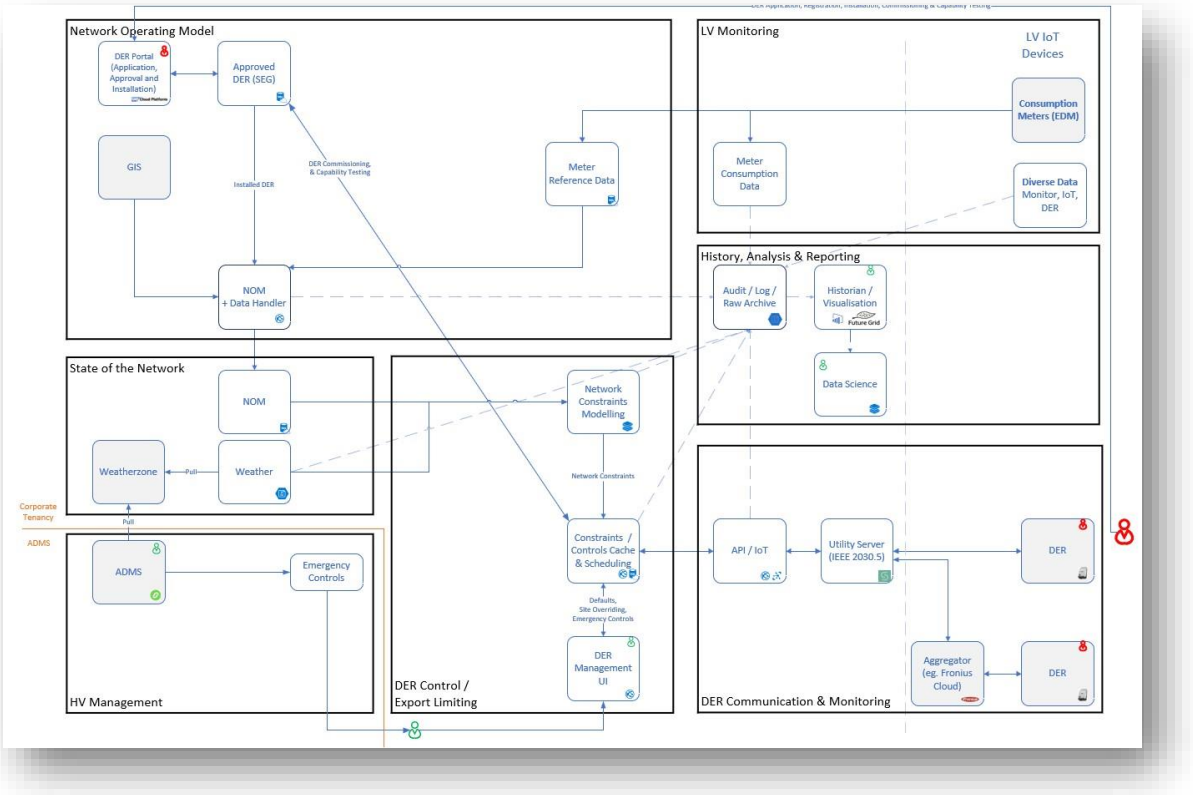
Core components of the solution include:

- **Constraints engine** which models the available and forecast hosting capacity for all 75,000+ distribution transformers every 15 minutes.
- **Flexible Exports core**, which converts the available hosting capacity into a schedule, or dynamic operating envelope, which is published to devices through the utility server. Furthermore, this component manages the device registration workflow and routes visibility data from the Flexible Exports inverters to the visibility and analytics platform.
- **API gateway**, which enables communication with the Utility Server DNSP interface.
- **Visibility, analytics, and reporting,** which houses the time-series data received from Flexible Exports devices.

- **DER management user interface**, which provides operators the ability to override the autonomous export limits generated by the constraints engine under emergency conditions.

Figure 1Figure 14 shows the functional architecture of SA Power Networks Flexible Exports operational systems.

Figure 14 Functional architecture of SA Power Networks DNSP operational systems



The systems were developed utilising an Agile methodology in close collaboration with SwitchDin due to the functional coupling between the Utility Server and DNSP backend systems. Functionality was delivered ahead of schedule and successfully enabled all functional use-cases over the duration of the trial.

3.5.2.2 Constraints engine approach

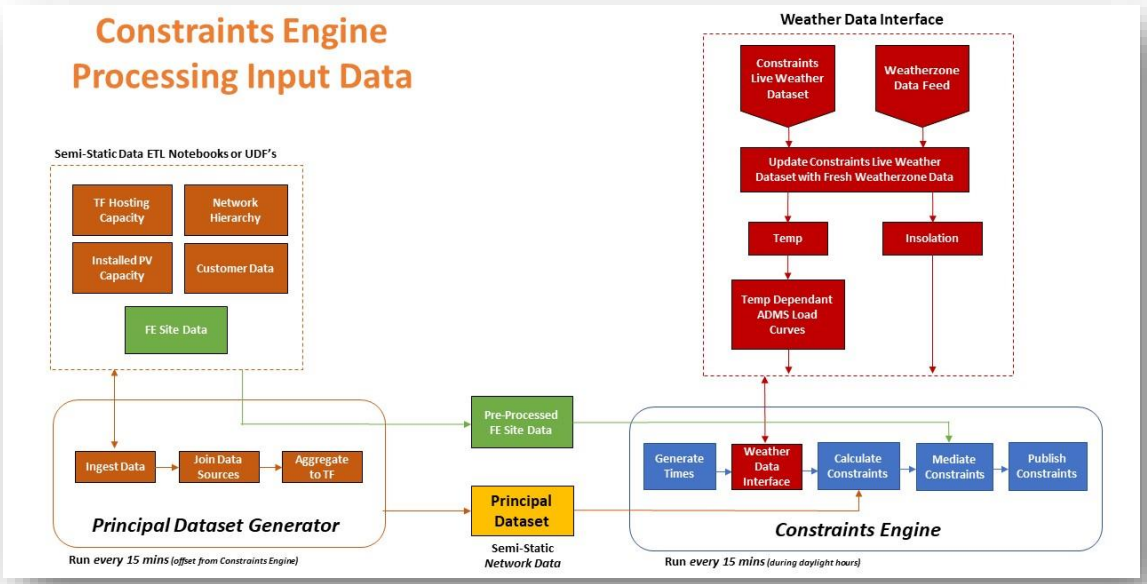
The Constraints Engine is a powerful tool that enables the calculation of network-wide flexible export limits. The system is built, maintained, and operated within the Azure Databricks platform which enables efficient, large-scale data manipulation. The algorithm leverages Apache Spark, a big data-analytics platform with parallel computing which can be scaled up and down based on current computational demand.

The engine runs autonomously every 15 minutes to generate and publish flexible export limits. As solar PV systems cannot be responsive to a forecast, near real time operating envelopes are generated.

The constraints engine runs continuously and processes weather inputs to dynamically calculate and assign export limits to specific sites. This allows for real-time adjustments to the export limits for customers.

To achieve this, the engine estimates load and generation at each NMI and aggregates this data to a transformer level. It then compares the calculation against the transformer's hosting capacity and assigns the remaining export capacity to Flexible Exports customers. See Figure 15.

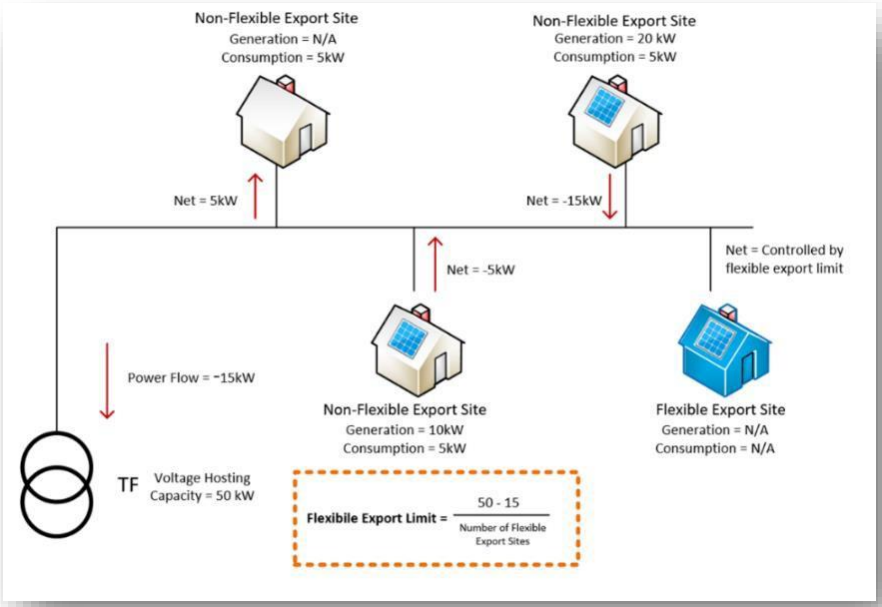
Figure 15: Constraints engine processing input data



As visibility of the low voltage network is limited, SA Power Networks utilised a template-based approach to calculating hosting capacity which was initially developed to support the Advanced VPP Grid Integration trial. In this model, a heuristic linking voltage constraints for customers on the LV network to a reverse real-power flow limit at the LV distribution transformer is computed for prototypical low voltage networks. This heuristic is known as the 'voltage hosting capacity' of the LV area. These remainder of LV distribution transformers not modelled in this approach are sorted into categories based on known characteristics, such as line length, network construction and customer distribution. A voltage hosting capacity is then assigned to each transformer based on category.

The simplified load-flow estimation method used by the Constraints Engine is depicted in Figure 16, this process is repeated every 15 minutes throughout daytime hours for the upcoming time window.

Figure 16: Example load-flow estimation method



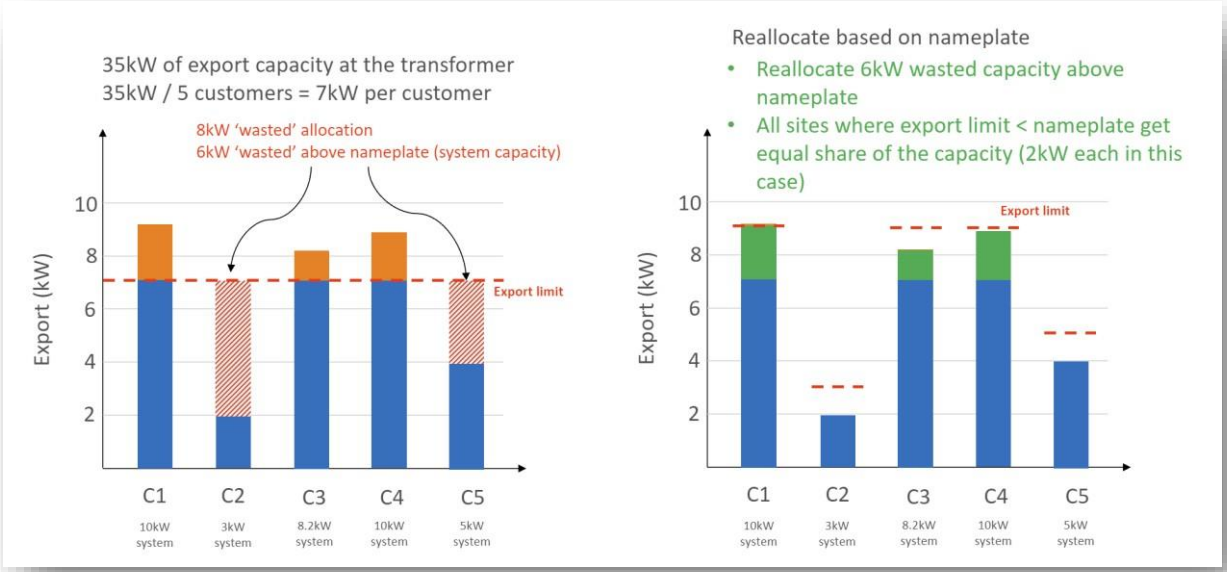
Once hosting capacity headroom is calculated, the constraints engine then allocates available capacity amongst Flexible Exports customers.

There are many approaches to allocating hosting capacity which vary in complexity, efficiency, and customer equity outcomes. Stakeholder engagement processes conducted by the ARENA DEIP Dynamic Operating Envelopes working group[7] found that there were mixed perspectives on the best capacity allocation approaches, but a small majority of participants preferred an 'equal allocation' based principle. Under this approach, all customers below a given constraint are allocated the same export limits which may be considered fairer than penalising end of line customers who have greater contributions to the constraint but may result in less hosting capacity being allocated overall.

SA Power Networks implementation of equal allocation applies at the LV distribution transformer. Using this model provides all customers an equal allocation which may result in customers with larger DER installations being curtailed more heavily. In addition, hosting capacity is only allocated to sites that have sufficient export capacity (e.g., a NMI with a 6kW PV system is not allocated a >6kW Export Limit).

[7] Find more information on the DEIP Dynamic Operating Envelopes Workstream at: https://arena.gov.au/knowledge-innovation/distributed-energy-integration-program/dynamic-operating-envelopes-workstream/

Figure 17: Equal hosting capacity allocation approach



To achieve these outcomes, the Constraints Engine uses an iterative reallocation algorithm, shown in Figure 17. The algorithm calculates a first pass export limit for all sites, and then performs a set number of additional iterations only on transformers where the sites are allocated neither the minimum (1.5kW) nor maximum (site installed AC capacity) export limits.

3.5.3 AusNet

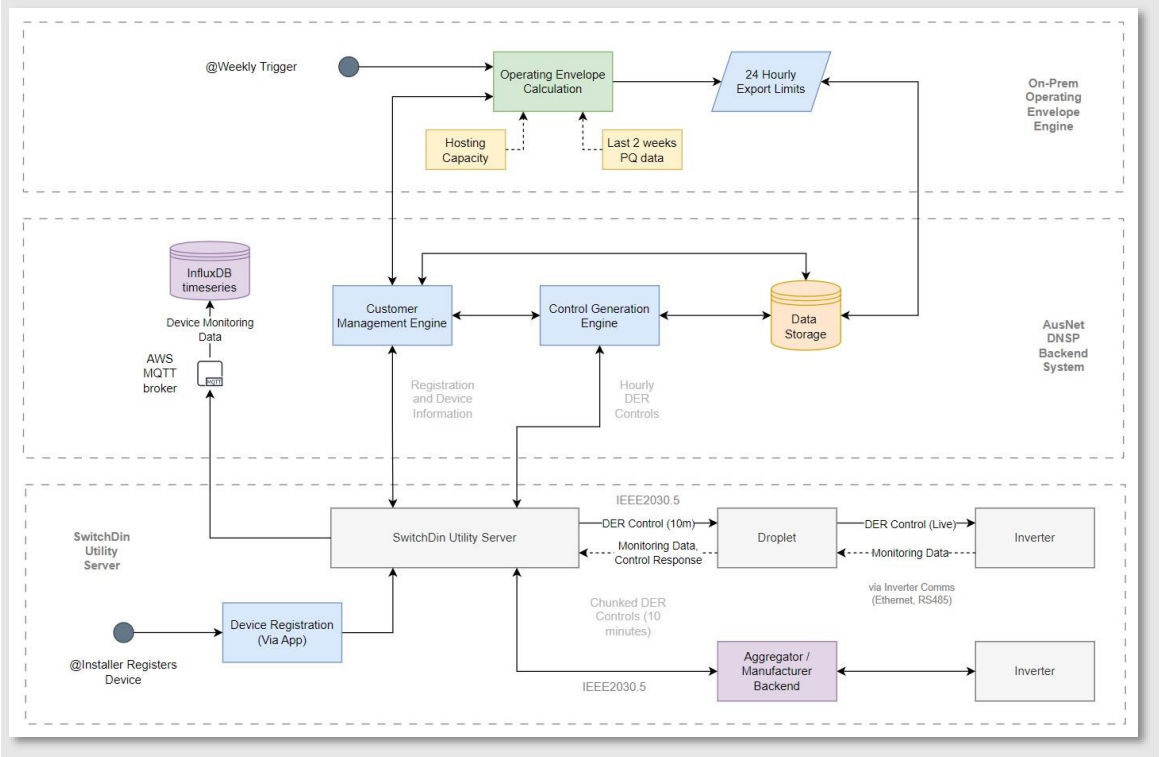
2.1.1.1 Operational Systems Build

AusNet's trial system for Flexible Exports is divided into three distinct parts, the operating envelope calculation engine, the DNSP backend system, and the AusNet Utility Server instance, all three-facilitating calculation, transmission, and monitoring of Flexible Exports.

The operating envelope calculation engine builds on the existing substation hosting capacity estimation engine previously developed by AusNet. It integrates these with data from AusNet's fleet of AMI meters for the customers participating in the trial. This provides the engine with visibility of the local conditions that each customer experiences throughout the day, and the engine uses voltage-based prediction to determine the impacts of solar exports for each customer. Hosting capacity is evaluated weekly and triggers an update to the operating envelopes which are calculated at the same frequency. These are then pushed to the DNSP backend system, which AusNet hosts in AWS (Amazon Web Services). The operating envelope calculation engine runs on AusNet's Smart Networks analytics platform which hosts the substation hosting capacity engine and AMI meter data.

The DNSP backend system is responsible for management of customers, flexible export limits, and interfacing to the Utility Server, which ultimately sends limits to connected devices. Operating envelopes, timeseries monitoring data, and customer/device metadata are stored here. The backend engine applies a set of operating envelopes in hourly intervals as IEEE2030.5 DER controls daily, that is, a set of 24 hour-long limits are generated overnight based on the current operating envelope and refreshed once a day. Monitoring data is collected from the devices connected to the Utility Server through MQTT, and a custom API integration also facilitates customer registration to the system. The DNSP backend is implemented utilising server-less architectures.

Figure 18: AusNet's trial system for Flexible Exports



3.5.3.1 Constraints engine

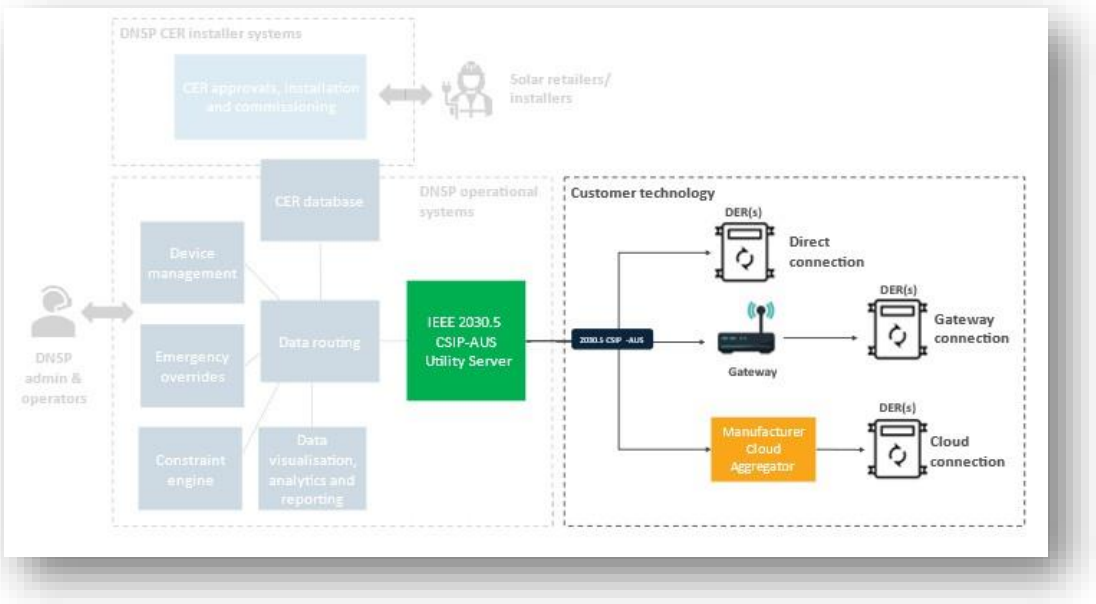
The Flexible Exports constraint engine uses a heuristics-based statistical approximation methodology to calculate flexible export limits for every eligible connection point. The engine takes both network and local constraints into consideration to ensure systems operate within safe operating limits.

Hosting capacity is derived using historical AMI Smart Meter Power Quality data, network hierarchy and substation rating. The resulting statistical model then uses historical network data to estimate future network normal conditions to calculate the total hosting capacity and the corresponding remaining export capacity for a distribution substation.

The operating envelope engine uses the substation hosting capacity and participating connection point AMI Smart Meter Power Quality data to calculate the dynamic export limit for each participating customer on a given substation. The engine allocates export limits as a proportion of each customer's constraint relative to each other.

3.6 Customer technology

Figure 19: Customer technology



Customer technology includes IEEE 2030.5 CSIP-AUS compliant smart inverter systems and gateway devices that can receive and enact flexible export limits. SwitchDin and Fronius both developed compatible customer technology in the trial which will be explored in this section.

3.6.1 SwitchDin development

SwitchDin offer a gateway device called the Droplet, which has the capability to communicate with and orchestrate inverters from many manufacturers. IEEE 2030.5 CSIP capability was added to the Droplet to support Horizon Powers' Onslow DER trial[8], which formed the basis of the client used in the Flexible Exports trial. Changes made were incorporated into CSIP-AUS. Key additional features included:

- Capability for site-wide export limiting DER control opModExpLimW that was ultimately incorporated into CSIP-AUS
- Modifications to the installer process to support enrolment in the SA Power Networks and AusNet Flexible Exports programs
- Support for additional inverter brands with the CSIP-AUS Flexible Exports client.
- Support for additional site metering configurations.

The Droplet was the first Flexible Exports customer technology delivered in the trial, and the only compliant equipment at trial launch. The inverter brands supported by the Droplet in the trial included:

Table 3: Inverter brands supported by the Droplet in the trial

Inverter manufacturer	Inverter model	Capacity (kW)	# Phases	Flexible connection
Fronius	Primo (SnapINverter)	3.0-8.2	1	SwitchDin Droplet

[8] https://www.horizonpower.com.au/your-community/getting-future-ready/onslow-distributed-energy-resources-management-system-derms/

Inverter manufacturer	Inverter model	Capacity (kW)	# Phases	Flexible connection
Fronius	Symo (SnapINverter)	3.0-20.0	3[9]	SwitchDin Droplet
SMA	Sunny Boy AV-41	3.0-6.0	1	SwitchDin Droplet
SMA	Sunny Tripower AV-40	3.0-10.0	3[3]	SwitchDin Droplet
GroWatt	MIN TL-X	2.5-6.0	1	SwitchDin Droplet
ABB Fimer	UNO-DM-PLUS-Q	3.3-6.0	1	SwitchDin Droplet

3.6.2 Fronius customer technology

Fronius developed support for their Gen24 range of inverters using the cloud connection model. The design leverages Fronius' existing SolarWeb cloud system that has existing remote communication and control capability with Fronius inverter systems.

Fronius had previously commenced development of an IEEE 2030.5 CSIP compliant aggregator to support the Rule 21 requirements in the US which was never finalised. This option was not scalable and therefore not viable. A rebuild was developed with the inclusion of CSIP-AUS as a basis. Development included:

- Capability to support site-wide export limiting using the CSIP-AUS OpModExpLimW DERControl
- Control path between the CSIP-AUS aggregator and the inverter
- Additional capability in inverter firmware including:
    - Scheduling and failsafe capability
    - Acceptance of control commands from a cloud (including the Cybersecurity development required)
    - Storing and acting on schedules
    - Transition from instantaneous to average monitoring data
- Device registration process within the commissioning workflow
    - Separate website and manual process developed to support the trial
    - Automated in band process through SolarWeb portal developed to support BAU

[9] Note the AusNet Services trial is not yet testing 3-phase inverters

3.7 Field trial execution

Once the offers and technology were developed, the Flexible Exports field trial officially commenced on 23 September 2021.

Detailed planning activities were conducted in the lead up to the launch of the trial, including:

- Development of the customer offer
- Development of stakeholder and customer engagement plan
- Onboarding of a customer research partner (SEC Newgate)
- Change management planning for each business

The field trial was then executed through:

- Pre-trial field test – This involved a field test for friendly customers to conduct end to end connectivity and systems testing in a production test environment to smooth any onsite installation or operational issues.
- Field trial – The Flexible Exports offer was made available to eligible customers to understand the installation process and test the reduced export limits, the customer experience, the customer value, and support arrangements. A reduced number of customers were recruited for the research activities of data collection and key learnings.
- Scale up – This stage was intended to either extend Flexible Exports into a standard connection offering or an option to revert customers if the trial findings led to the discontinuation of Flexible Exports. The option to revert was not required, and all customers remained on enduring Flexible Export offerings.

3.8 Customer offer development and overview

Historically, SA Power Networks offered an automatically approved fixed export limit of 5kW per phase to customers who install small embedded generators (SEG), regardless of their network location. Modelling and operational observation have determined that 5kW per phase export limit is no longer sustainable. To that end, on 23 September 2021, SA Power Networks began classifying selected zone substation areas as congested, reducing the fixed export limit to 1.5kW per phase.

While the 1.5kW static limit is required to prevent network congestion in the worst-case conditions, the network has significant capacity to enable export majority of the time. These congested areas were chosen as trial areas and customers connecting new solar or upgrading their systems were offered Flexible Exports as an alternative to a fixed 1.5kW export limit. The Flexible Export offer allowed customers with the opportunity to export between 1.5kW and 10kW per phase, up to double the traditional 5kW export limit, and was made available on 23 September 2021. It was anticipated that the 10kW export limit would be available for 98% of the time during the trial period.

Similarly, AusNet started to implement reduced export limits on a small number of low-voltage substations as they reached capacity in 2017. This was also due to the increase in solar rooftop penetration on AusNet's network, both the number and size of residential installations, and the need to maintain safe operating voltage.

Export limits with a standard static of 0kW or low kW exports, following a technical assessment, are increasingly becoming an offer on congested substations in various areas scattered across AusNet's entire Victorian network rather than geographically clustered.

AusNet developed two Flexible Exports customer offers for the trial:

- A 'retrofit' option for customers who have been assigned a constrained fixed export limit of below 3kW and have already installed a solar inverter which would be compatible with Flexible Exports

- An opt-in offer for new solar customers looking to install solar and were advised they were eligible for constrained fixed export offer of below 3kW

The first 'retrofit' customer install occurred on 16 August 2021, and the expression of interest for new customers to join Flexible Exports was launched on 23 September 2021.

Table 4 compares the offers from SA Power Networks and AusNet.

Table 4: Comparison of SA Power Networks and AusNet customer offer

	SA Power Networks	AusNet
Existing export limit arrangements (DER SEG <30kVA)	Automatic approval for 5kW per phase export limit, regardless of network location.	Automatic assessment for export limit between 0kW-5kW per phase, depending on available local hosting capacity.
Offer	All new and upgrading customers in congested areas have a choice between: Fixed export (1.5kW per phase) Flexible Exports trial (1.5-10kW per phase) Exports expected to be at 10kW for 98% of the time.	Single phase (non-SWER) customers with existing zero export/reduced export may join the 12-month trial to receive up to 5kW Flexible Export.
Eligibility	Available in congested zone substation areas. Zone substations classified as congested are: Sheidow Park Blackpool Blackwood Oaklands Customers must install a compatible equipment and have an internet connection[10].	Customers who have an auto-assessment outcome of <3kW export[11]. This includes: Existing 'retrofit' customers with a compatible inverter + internet New customers choosing a compatible inverter + internet Two-step eligibility assessment process: Hosting capacity assesses available 'headroom' on a substation + network health Engineer assesses 12 months of substation Power Quality data
Approach	All inverter manufacturers, retailers, and installers able to participate, aiming to mirroring BAU conditions beyond the trial.	Offered as a 12-month trial – trial agreement is an addendum to the standard connection offer MSO.

[10] Internet connection already required for remote disconnection requirements introduced in the Smarter Homes program; https://www.energymining.sa.gov.au/industry/modern-energy/solar-batteries-and-smarter-homes/regulatory-changes-for-smarter-homes#%3A~%3Atext%3DRemote%20disconnection%20and%20reconnection%20requirements%2Cregistered%20with%20the%20Technical%20Regulator.%26text%3DNote%20that%20assessments%20of%20prospective%2Clist%20will%20be%20frequently%20updated

[11] <3 kW static export chosen as eligibility criteria as these customers are predicted to receive most value from flexible export connection up to 5kW.

	SA Power Networks	AusNet
	Customers offered Flexible Exports for the life of their installation or revert to 5kW in the event Flexible Exports is not continued beyond the trial.	'Retrofit' customers already installed and eligible for the trial identified by AusNet and directly recruited to the trial. New installations with restricted export limits encouraged to submit an EOI. trial promoted direct to installers and to customers through website, social media, and word of mouth.

A customer or their installer must install Flexible Exports compatible inverter equipment to participate in the trial. Table 5 shows the compatible inverters that were available during the trial.

Table 5: Flexible Export Compatible Inverters

Inverter manufacturer	Inverter model	Capacity (kW)	# Phases	Flexible connection
Fronius	Primo (SnapINverter)	3.0-8.2	1	SwitchDin Droplet
Fronius	Symo (SnapINverter)	3.0-20.0	3[12]	SwitchDin Droplet
SMA	Sunny Boy AV-41	3.0-6.0	1	SwitchDin Droplet
SMA	Sunny Tripower AV-40	3.0-10.0	3[3]	SwitchDin Droplet
GroWatt	MIN TL-X	2.5-6.0	1	SwitchDin Droplet
ABB Fimer	UNO-DM-PLUS-Q	3.3-6.0	1	SwitchDin Droplet

During the trial period, all systems required the installation of a SwitchDin Droplet to achieve Flexible Exports capability. Fronius, SolarEdge and SMA have developed or are currently working on "native" integrations which have inbuilt inverter software and do not require an external device to participate. Table 6 shows the list of technology compatibility from the trial partner inverter manufacturers and technology companies which have been completed during the lead up to the changes to SA Government regulatory changes (1 July 2023).

Table 6: Flexible Exports compatible equipment under development (from trial partners)

Inverter manufacturer	Inverter model	Capacity (kW)	# Phases	Flexible connection
Fronius	Primo Gen24+	3.0-6.0	1	Native*
Fronius	Symo Gen24+	6.0-10.0	3	Native*
SMA	Sunny Boy and Tripower	3.0-10.0	1-3	Native*
SolarEdge	EnergyHub	3.0-10.0	1	Native*

[12] Note the AusNet Services trial is not yet testing 3-phase inverters

Inverter manufacturer	Inverter model	Capacity (kW)	# Phases	Flexible connection
SolarEdge	Genesis	3.0-10.0	1	Native*
SolarEdge	EV Charging Inverter	3.0-5.0	1	Native*
SolarEdge	Three Phase	5.0-33.3	3	Native*

*Does not require additional hardware to participate

3.9 Recruitment methodology

The approach to customer recruitment undertaken SA Power Networks and AusNet was different due to the historic export arrangements and policy regulations.

Relatively early in the trial, it was realised that the restricted amount of compatible technology available was a barrier to some solar retailers recruiting customers, especially in cases where they were not able to offer compatible equipment. Both SA Power Networks and AusNet adapted by taking a stronger role in recruitment, including direct contact with customers.

3.9.1 SA Power Networks

SA Power Networks' trial was developed with a structure to mirror a business-as-usual service offering as to enable a smooth transition to scale at the end of the trial. Installers were not specifically engaged to work on the trial and therefore the process relied on solar retailers and installers to recruit customers to the new connection offer. The areas of the trial were determined by congested areas as listed in Table 2.

During the trial the available equipment was from inverter manufacturers who were participating in the trial. SA Power Networks engaged SEC Newgate to assist with to both develop customer messaging and undertake customer research to develop a richer understanding of the customer experience and help identify where barriers to uptake might exist.

Figure 20 shows the process for solar retailers and installers within the end-to-end solar journey, steps one to three relate to the recruitment of customers to the offer and the green boxes highlight changes to previous approach.

Figure 20: Changes to end-to-end solar journey

The existing SmartApply is SA Power Networks DER connections approval platform. As a part of the trial a new "options check" step has been added to SmartApply to enable a solar retailer or installer to determine whether a customer is in a congested area and whether Flexible Exports is available.

This presents a key change for the solar industry, where historically all applications in South Australia were auto approved for 5kW per phase export, solar retailers must now check what export options are available for their prospective customer prior to making a sale.

3.9.2 AusNet

The Flexible Exports trial was seen by AusNet as an opportunity to engage customers and installers with positive messaging on the innovative advancements being delivered to increase capacity on our network. AusNet initially planned a network-wide recruitment strategy to raise awareness across eastern Victoria including media and social media promotion. This did not commence as the hosting capacity algorithm was first deployed but had not yet built up enough 'confidence' in network conditions, and it was found that only around 30% of customers assessed for trial had eligible connections.

The engagement strategy was repositioned and instead a campaign was launched aimed at solar installers and recruiting their export constrained customers. AusNet did not have a strong history of installer engagement prior to the trial, and this was work that had to be built up over time and resourced from the trial team. AusNet produced promotional and training collateral aimed at installers and produced promotional collateral for installers to use to communicate with their customers.

Initially, the offer was developed for existing solar customers with a fixed export limit below 2kW. Flexible Exports of up to 5kW were seen as a clear benefit over a fixed 2kW. With the evaluation customers were invited to present an expression of interest in participating in the trial.

The customer offer evolved over the course of the trial through an agile approach. Customer uptake increased with customers below 3kW limit being invited to participate later in the trial. AusNet arranged the installation of additional hardware as part of the retrofit installations.

The AusNet trial offer was also open to customers with new installations which received a low fixed export limit through the connection assessment process. No specific areas on the network were targeted. As a part of the installation process customers were required to install compliant systems (i.e., without unauthorised exports).

A direct outreach to customers approach was implemented during the trial with calls made to potentially eligible solar customers.

3.10 Recruitment findings

3.10.1 SA Power Networks

3.10.1.1 Industry findings and response

The original vision for trial was an industry led recruitment rather than led by trial teams to better model post-trial conditions. Typically, recruitment trials of this nature would be conducted by selected solar retailers and installers, but it was determined that this would not truly measure broader industry capability to support Flexible Exports. However, this approach required extensive communication and engagement with the majority of the solar industry in South Australia.

The team worked closely with solar retailers and installers to increase awareness and facilitate the process by:

- preparing guides and instructions to assist with installation and commissioning of compatible equipment.

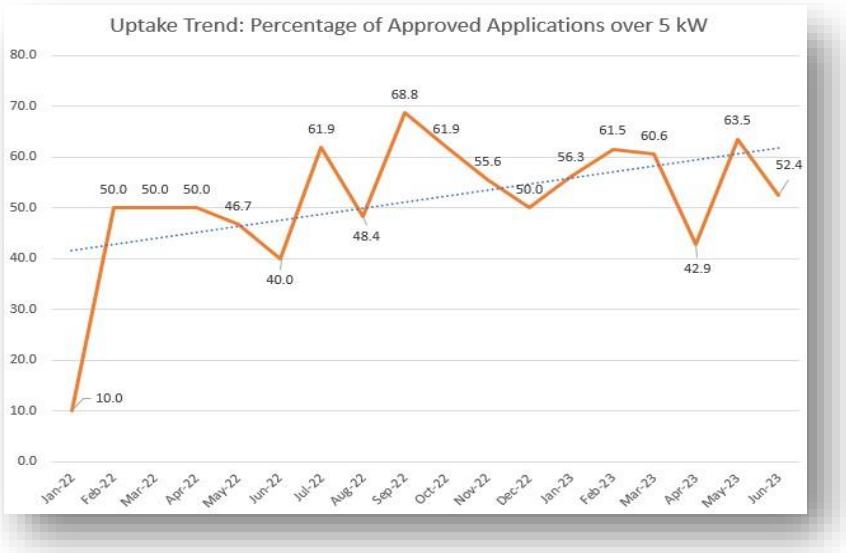
- establishing Solar Industry Reference Group (SIRG) consisting of solar retailers, and Installers to co design aspects of the solution and ensure it was as installer friendly as possible.
- hosting webinars to broadcast information in the lead up to the trial.
- additional broadcast communication through existing channels such as Industry News and Talking Power publications, and the SA Power Networks website.
- developing a free training course on Flexible Exports hosted and promoted by the CEC.
- incentivising installers to participate in training to successfully complete courses resulted in 30 CPD points.

A range of engagement activities was undertaken to seek solar retailers and installers feedback on their experiences with the Flexible Exports trial. A survey mid-way through the trial was sent to all solar installers and retailers and received responses from 100 participants. High level findings include that:

- Solar retailers and installers typically align to a small number of inverter brands that are embedded into their sales and installation processes. Having limited solar equipment compatible with the Flexible Exports trial meant that a large proportion of solar retailers could or would not offer Flexible Exports to their customers.
- Limited understanding or confidence that the Flexible Export offering would significantly increase customer's export capacity – installers sought evidence or case studies to be able to share with customers as well as increase their own confidence.
- 72% know about Flexible Exports with, with 32% indicating they knew 'a fair amount' and 24% indicating that they knew 'a lot'.

As they trial progressed, data indicates that increased understanding of significant additional benefit of installing a solar inverter >5kW (above 5kW) to take advantage of double peak export compared to the traditional 5kW limit. Figure 21 illustrates how customers increasingly chose larger inverters, with installed inverter capacities >5kW on the Flexible Exports options rose from four to 34 applications during the first six months of the trial and have remained at a higher rate than the early trial installations.

Figure 21: Uptake trend Percentage of approved applications over 5kW



SA Power Networks have also received numerous requests from installers and customers outside of eligible congested areas wanting to participate or know when the offer would be available in their area.

3.10.1.2 Customer findings and response

Trial research partner, SEC Newgate, were engaged to survey participating customers on their sentiment towards Flexible Exports. SA Power Networks also surveyed ten customers who chose the 1.5kW fixed option to ascertain information about the choice these customers made. The survey found that 8 out of 10 customers were not made aware of the flexible option. Through this process six customers changed their application from Fixed to Flexible Exports.

The discovery that a lack of customer awareness formed a barrier to customer uptake, SA Power Network decided to pursue direct customer engagement. The aim of the engagement was to ensure potential solar customers were aware of their options and well equipped for conversations with solar retailers and installers. This engagement took the form of:

- Mailout of information to potential customers within congested substation areas (n = 3,961).
- Social media promotion including information about the offer, targeted to customers in congested substation areas.

The mailout received limited responses and resulted in only one telephone enquiry and no perceivable increase in trial participation.

The social media promotion included a paid social media and search engine marketing campaign to promote and build awareness of Flexible Exports, targeting homeowners in eligible geographic areas. Some example social media graphics from the promotion can be found in Figure 22.

Figure 22: Example social media tile graphics

An initial promotion was presented across metropolitan areas, then a second delivery targeted trial locations. The first half of the campaign resulted in 7,898 visits to the website page, from the wider target audience, and the second half of the campaign resulted in 1,231 visits to the website, from the geolocation targeted audience.

The campaign included placing ads on Facebook and Google. Once people clicked on the ads, they were taken to SA Power Network's Flexible Exports campaign landing page[13], which was set up specifically to track the effectiveness of the social media promotion. The landing page included links to:

- Informative video introduction to Flexible Exports
- Checklist for questions to ask a solar retailer about export options

The following learnings have been gained through comments responses to the social media:

- Customers are interested in the changes happening in their area and want to know if or when Flexible Exports will be available to them.
- Customers are looking for a trustworthy party who can help them with Flexible Exports and related solar and energy issues.
- Our customer research shows that customers have a high appetite for this service, and a strong understanding of the benefits of participating, compared to having fixed export limits that apply all year round.
- The financial benefit is not seen as the only driver, customers also cited that community and environmental benefits associated with unlocking more solar on the network.

Of the 1222 small embedded generator applications within the eligible substation areas, 36% of chose the Flexible Exports option over 1.5kW fixed export. As indicated before, we expect the greater uptake of fixed export customers was due to the limited compatible equipment options, resulting in many solar retailers not offering Flexible Exports to customers. This is supported by 82% of customers who did choose to install Flexible Exports compatible equipment taking up the offer, including the additional cost of installing a SwitchDin Droplet device.

This hypothesis has further been validated by early uptake of the Flexible Exports BAU option where the vast majority of inverters support Flexible Exports. Approximately than 85% of eligible customers have selected the Flexible Exports option in the first two months of operation.

Figure 23: Flexible Export uptake in congested areas

[13] https://www.sapowernetworks.com.au/industry/flexible-exports/why-flexible-exports/

3.10.1.3 Introducing a focus on compliance

During the trial there were a number Flexible Export installations which were identified as not compliant, and steps were taken to manage the compliance issues manually. Compliance to the standards and regulations is vital for the success of Flexible Exports and the security of the grid. A decision was made to develop a more sophisticated approach to compliance for solar installations which is a broader program of work than the Flexible Exports project. Further information about this program is included in section 5.1.3 of this report.

3.10.2 AusNet

In Victoria the trial was structured to test and validate objectives and develop a solution that would be agile enough to evolve and incorporate industry needs. This trial also sought to inform future implementation of Flexible Exports nationally. In Victoria specifically, the need to adopt alignment across the five distribution networks would lead to the greatest customer benefits.

3.10.2.1 Customer and installer findings and response

In the initial approach customers joining the trial were asked to pay for the gateway device as part of their installation as it was predicted that the small cost could be recouped through feed-in-tariffs across the trial period, it was found that upfront cost of installing compatible systems during a limited trial period might be seen not comparable with benefits realised. The approach was changed, and AusNet arranged to subsidise new installations for customers to join the trial. All customers have been advised they can remain on the Flexible Exports offer post-trial.

The focus from presenting the offer to installers, moved to a direct outreach to customers which provided an opportunity to test the customer offer and messaging. Key messaging to AusNet customers was to 'help us improve our network'. This message didn't resonate as strongly with installers, but it was found that most trial expressions of interest came from customers seeking solutions to a constrained export connection offer. Installers were less likely to seek out options for customers to increase export other than a paid technical assessment.

Most installers working on the AusNet network who had experience of customer connections with constrained export limits had already developed their own strategies for managing these connections and were not motivated to promote the Flexible Exports offer. We learnt that their workarounds for export constrained customers including:

- recommending their customer pay for a technical assessment of their connection
- using the export constraint to up-sell their customer with a battery or down-size an installation size to just cover customer consumption needs
- or ignore the contractual export limit and allow full export, in breach of the customer's connection agreement with AusNet

Several stakeholders are associated with the customer recruitment and decision-making process. There is the customer/homeowner, the solar retailer, and the solar installer. Through trial it was found that successful recruitment relied on engagement with all three stakeholders. Each stakeholder had different motivations and there are complexities reaching each type of stakeholder, including reaching them at the right point of their solar journey. An automated Flexible Export connection as part of AusNet's online application tool would assist with the recruitment of trial participants. Engagement resources are better utilised to deliver more and consistent outreach to solar retailers and training for installers, and a clearer call-to-action to engage constrained customers.

4 Insights

4.1 Research hypotheses and questions

Prior to the trial, we determined several research questions to be answered. This section describes the findings against each, along with some additional insights gained over the course of the trial.

4.2 Customer experience

SEC Newgate were engaged to conduct the customer research on the project to develop a deeper understanding of the customer perception and acceptance of the Flexible Exports connections.

The surveys were co-designed and both qualitative and quantitative methods were employed throughout the trial including:

- An initial online benchmark survey including all customers who agreed to participate
- In depth phone interviews mid-way with trial and non-trial customers
- A final online survey to identify and changes to baseline findings
- Analysis to help understand the key drivers behind the responses received from customers. Detailed findings can be found in the *Flexible Exports for Solar Customer research report*[3] SA Power Networks also interviewed two customers for case studies during the later stages of the trial.

4.2.1 Research question 1: What is the customer perception/experience of the Flexible Exports service?

Some summary statistics have proven that customers accept Flexible Exports and the reasons for the introduction of this service. They also believe that Flexible Exports is a better option for each network than a fixed export limit.

Flexible Exports received a Net Promoter Score of +20 (a good or favourable score), meaning most participants were likely to speak well of the offer to others.

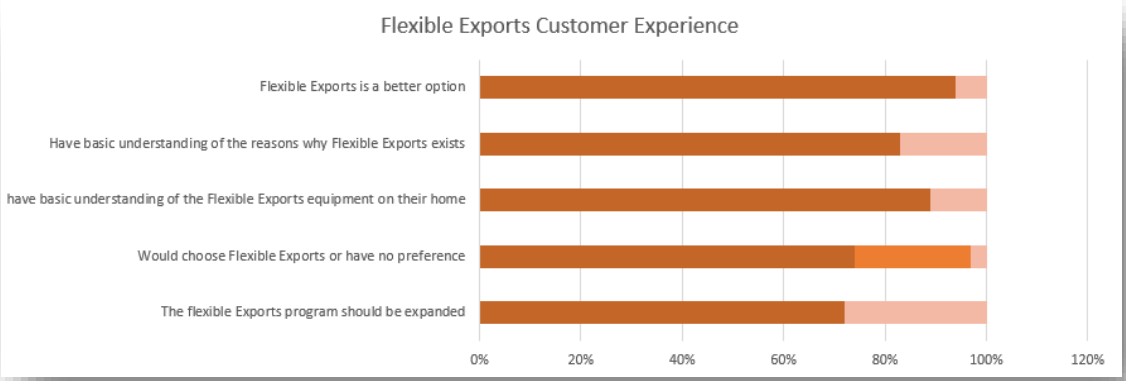
The main reasons for a high level of satisfaction with Flexible Exports were seeing a decrease in electricity bills and a positive perception of the technology – enabling them to export more than they might otherwise be able to and increasing renewable energy on the grid. These were the main reasons participants signed up for Flexible Exports."

4.2.1.1 SA Power Networks

To inform the answer to this research question, Newgate research has provided some insights into customer satisfaction with the Flexible Exports service.

[3] https://arena.gov.au/knowledge-bank/sa-power-networks-flexible-exports-for-solar-pv-trial/

Figure 24: Customer research end of trial findings

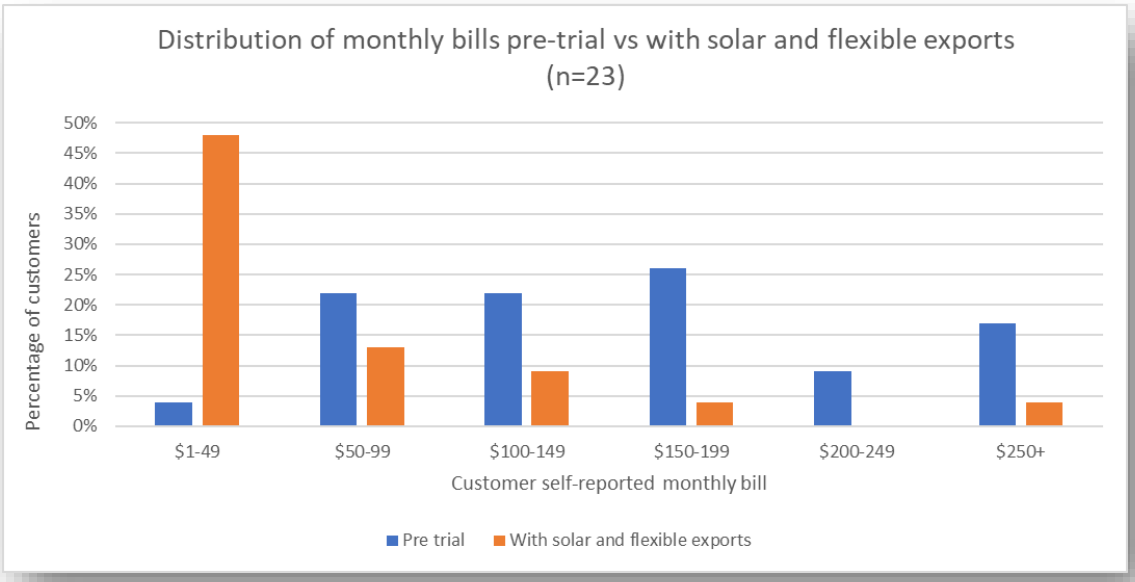


Some additional insights seen in Figure 24 show that customers believe Flexible Exports is a better option than a fixed limit and that the program should be expanded in South Australia.

- 72% believe the program should be expanded, with 76% indicating SA Power Networks is strongly supporting the growth of solar in South Australia.
- 97% of customers stated they would choose Flexible Exports or have no preference with only one person advising they would not choose it again citing that they have a small system (<5kW) and would not realise in their opinion the benefits.
- 8 out of 10 Customers have an understanding of Flexible Exports and why this is being trialed in the State and were able to articulate why it is needed and the benefits.
- 94% of customers agreed Flexible Exports was a better option for them.

Following installations and an opportunity to see benefits of the installation 66% of customers agreed that the performance of Flexible Exports technology has exceeded their expectations. Where customers have undertaken bill comparisons and reported their findings to Newgate that they have significant (mean average approximately two thirds' savings) on their bills for the same period last year.

Figure 25 Distribution of monthly bills pre and post solar and flexible exports



The example chart Figure 26 site monitoring data for one of SA Power Networks' trial customers over four days in March. The upper dashed line at -1.5kW (with negative indicating exported energy) shows the amount of power that could be export by this system under a fixed plan, amounting to 56kWh, with the lower dashed line showing the actual given limit of 8.2kW as per inverter size, exporting a total of 175 kWh over the 4 days.

Overall satisfaction is higher for those customers who installed larger systems (>5kW) is seen with majority of all customers showing an overall increase or same level of satisfaction with Flexible Exports through the trial (90% of those customers whose satisfaction stayed the same have a high level of satisfaction at the benchmark survey).

Figure 26: monitoring data - 8.2 kW Fronius

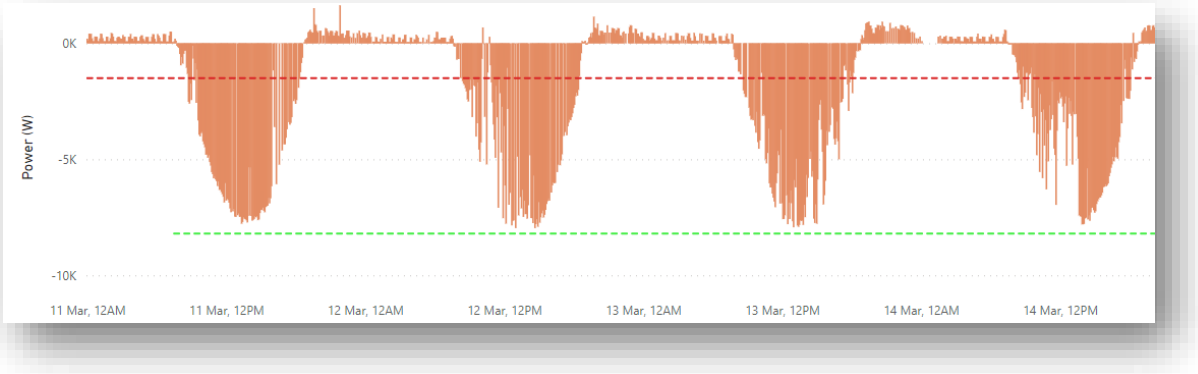
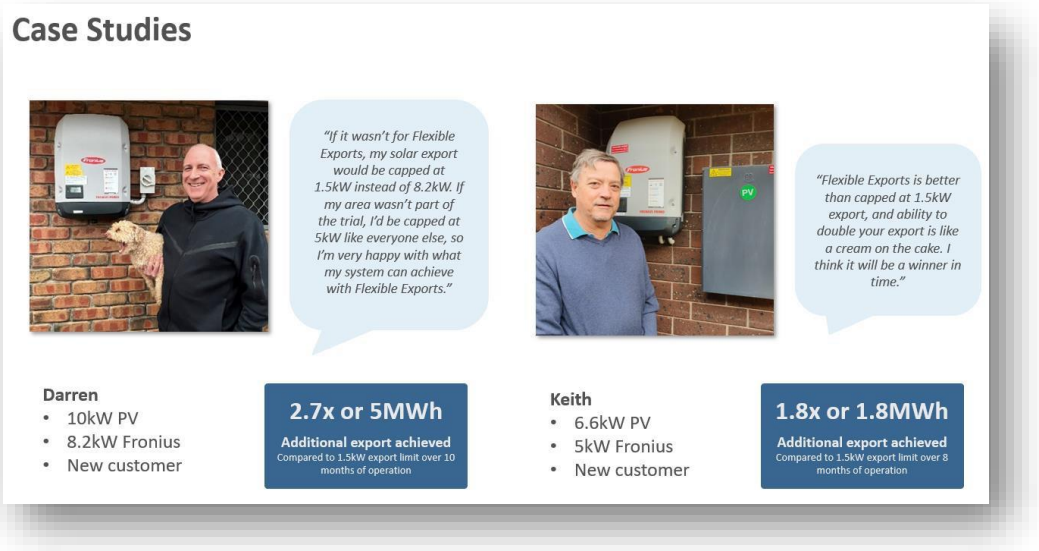


Figure 27 Highlights two case studies from trial participants that revealed more in-depth information about customer satisfaction. The key measure of value unlocked for customers in the trial is the exports achieved greater than what would have been available under the 1.5kW fixed export offer. Combined with the customer research findings, customers have shown to have an accurate and positive perception of Flexible Exports.

Figure 27: Case studies



4.2.1.2 AusNet

A key objective of the trial was to explore the customer experience of Flexible Exports offer and test customer acceptance.

A strong focus of the messaging for AusNet customers has considered their role in the transition to a net zero carbon future , and a focus for surveys has been on building social license for export management. In earlier phases of the trial, collateral was developed, and messaging tested to ensure that it resonated with customers and encouraged them to participate. This led to the development of website materials and other collateral which were provided to solar retailers and later targeted directly at customers.

The strict eligibility criteria meant that AusNet targeted information to customers who may be eligible and potentially interested in participating in the trial – the only negative perceptions directly fed back to AusNet from customers was from customers found to be ineligible for the trial and having to remain on a fixed constrained export limit.

Newgate research has provided insights into customer satisfaction with the Flexible Exports service.

- 63% of customers indicated their energy exports exceeded their expectation
- 80% were satisfied with clarity and timeliness of information they received in lead the installation
- 78% comfortable with the need for system to be connected to the internet

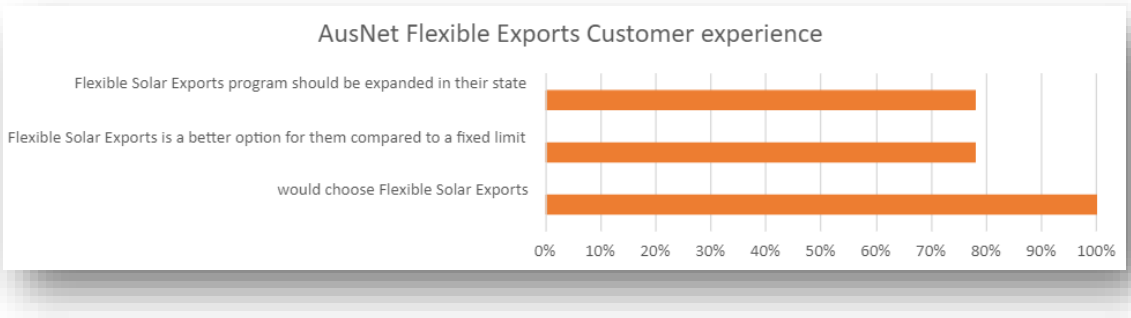
Survey findings show customer satisfaction for the Flexible Exports offer is high, and the majority of customers would recommend the offer to their friends, family, and neighbours. Feedback has been received throughout the trial about the transparency of available export information – customers were interested:

- to know what export limit that they were being sent
- information about how operating envelopes is calculated and explanations for curtailment
- better and more timely alerts for any system errors (e.g., loss of communication to inverter) and troubleshooting information

Many of these customer requests will be able to be made more accessible to customers as Flexible Exports matures as a customer offer.

In Figure 28 AusNet participants were asked if they had to make the choice again, would they choose Flexible Exports or Fixed Exports? All said they would choose Flexible Solar Exports provides more insights overall customer experience.

Figure 28: AusNet Flexible Exports customer experience



The value proposition for AusNet customers has been obvious. The majority of customers recruited to the trial would otherwise have had a fully constrained export limit of 0kW, so even the initial 1.5kW export limit issued from the operating envelope once a customer is connected to the server

is better than they had previously experienced. Customer outreach gave AusNet the opportunity to reinforce to customers about changing their consumption habits to get the most benefit from their solar installation. And the SwitchDin StormCloud monitoring platform was sometimes a customer's first experience of monitoring their consumption (and generation) and they were surprised to understand that their systems did not have a lot of excess generation to export after consumption.

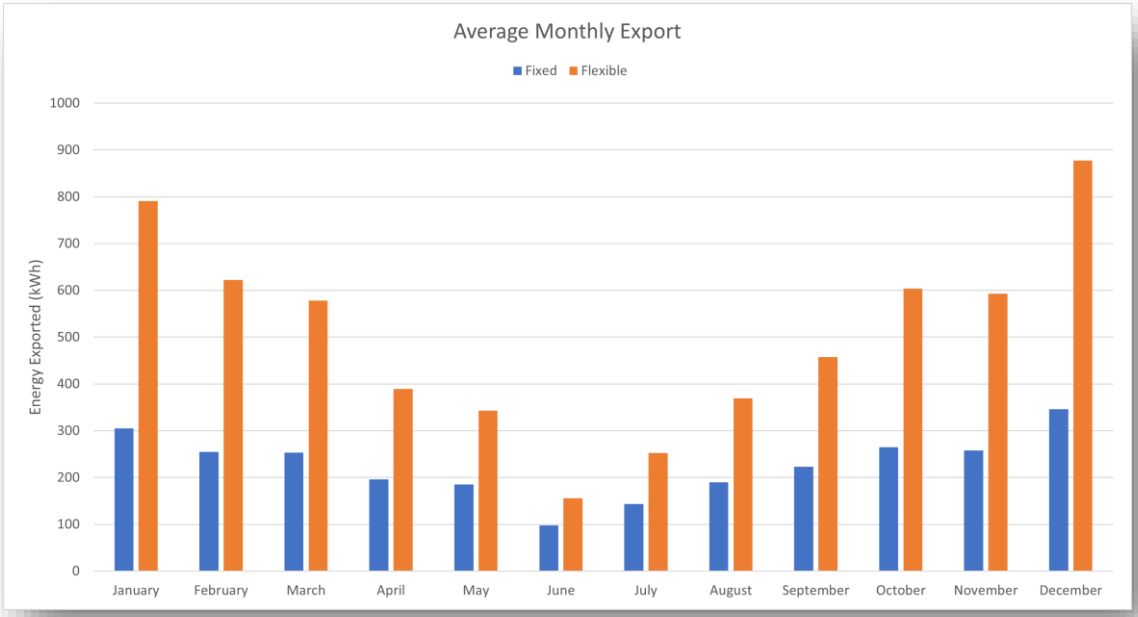
The main information sources that customer cited for their awareness of the trial were direct outreach from AusNet, word of mouth, and the website. Very few customers were referred from their installer, but some installers said they would be looking to increase awareness and have more opportunities to develop communications for customers when Flexible Exports becomes a standard offer across the network.

4.2.2 Research question 2: What are the costs and benefits for customers participating in Flexible Exports, as compared to a reduced static export limit?

4.2.2.1 SA Power Networks

Over the course of the trial, time-series data of five-minute granularity was captured by inverters and sent to SA Power Networks via the Flexible Exports interface, providing visibility of the exact quantity of energy exported under the Flexible Export option. This could be compared to the amount of energy released if the site had been on a fixed plan. Figure 29 shows the initial findings, using data from the start of the trial (24th July 2021) to the end of April 2023:

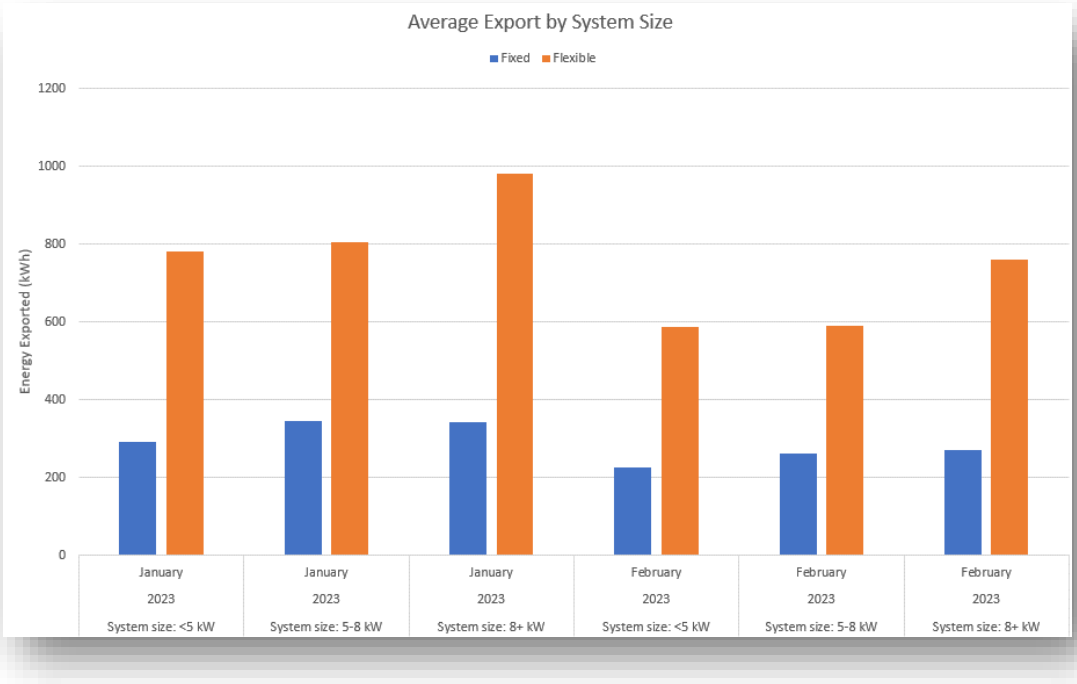
Figure 29: Average monthly energy released to grid per site.



As expected, the Flexible Exports option enabled more energy exports than the fixed option every month of the year. Seasonal changes in PV facilitated more energy exports in the spring/summer months, but overall, the ability to consistently export more energy is a major benefit available to Flexible Export customers.

Figure 30 shows the average energy exported by system size for devices online for the entirety of the January 2023 – February 2023 period. As expected during the summer months, devices on a Flexible Export plan were able to export well above double the amount of energy compared to the fixed option across all system sizes. Larger system sizes can expect to see higher energy exports overall, as the 10 kW flexible limit facilitates a much larger energy export for devices.

Figure 30: Average export by system size

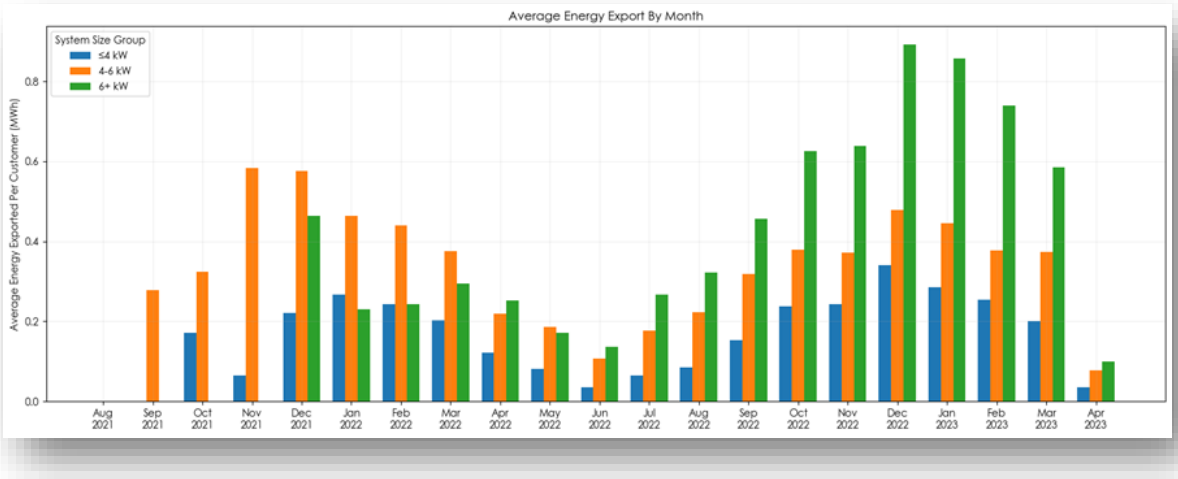


4.2.2.2 AusNet

For AusNet, the target customers for the Flexible Exports trial were in the most constrained areas of the network, where customers are often restricted from exporting or have minimal export permitted. Thus, the key measure of value unlocked for these customers is either a notable increase over their current limit, or the ability to export any energy to the grid. In total to 1st July 2023, AusNet's flexible export customers have exported 154.62 MWh of energy to the grid.

Figure 31 shows the average energy exported per customer, per month, across customers with different PV system sizes. It should be noted when viewing these results that the bulk of AusNet Flexible Exports customers have systems in the 4 to 5 kW range – a total of 26 customers. There are 2 customers with systems smaller than 4 kW, and 4 customers with a system 6 kW or larger.

Figure 31: Average energy exported



A decrease in the energy exported in the winter months is observed as would be expected due to a decrease in generation and increase in self-consumption of the remaining solar. Over the lifetime of the trial the total and average monthly energy exports are presented below:

Table 7: Average export by system size

System Size	Trial Average Total Energy Export	Average Monthly Energy Export
Up to 4 kW	3395 kWh	179 kWh
4 kW up to 6 kW	7007 kWh	333 kWh
6 kW or greater	7564 kWh	444 kWh

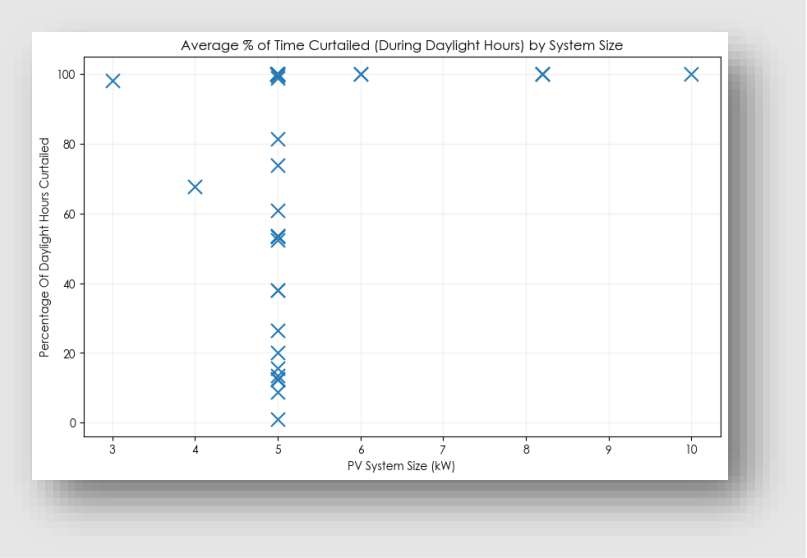
AusNet currently has one customer participating in the Flexible Exports trial who was previously assigned a 2.09kW export limit. This customer has exported an additional 3303 kWh of energy compared to their static limit over their time in the trial since mid-December 2021. This is a net increase of 60.4% in solar exports for the customer.

Additionally, the collective export permitted from the fleet of Flexible Exports inverters can be investigated showing the increased exports allowed over time as additional customers take part in the Flexible Exports trial. To get a view of the consistency of exports over time one can normalise this data, showing on average an approximate 3kW of export permitted across the fleet. Refer to Figure 32 .

Figure 32 : Aggregated and normalised export limit

Examining the average amount of time that the customer fleet has been curtailed shows that there is a wide variance in average system curtailment as presented below, owing to the target customer cohort being in the most constrained areas of the network.

Figure 33: AusNet average % curtailment



4.2.3 Cost of participation

During the trial, most installations occurred with the addition of the third-party device (SwitchDin Droplet) that adds an incremental cost to the installation. Native inverter solutions that do not require additional hardware do not incur this additional cost, further increasing the already present benefits of Flexible Exports.

4.3 Technology solution

Data collection over the duration of the trial allows the assessment of system performance, cost and scalability, with an eye towards identifying potential learnings for DNSPs hoping to implement a similar system.

4.3.1 Research question 3: To what extent can the Flexible Exports technology systems enable dynamic management of exports to meet the service objectives?

4.3.1.1 SA Power Networks

The three system communication components that can be assessed:

Constraint engine: The constraint engine achieved an uptime of 99.6% during daylight hours.

Utility Server: The utility server, which is deployed and operated by SwitchDin, and over the length of the trial had an uptime of 97.8%.

Inverter Communications: Using the daylight hours operating time of the constraint engine, devices were able to communicate 89.3% of the time. Noting that some systems may not be online in the first hours of the morning or last hours of the afternoon if there is not sufficient sunlight to wake the system, especially in the winter months. Outages to system integrations during the trial period helped inform areas for improvement in the operational monitoring and support of the solution. One example of this type of improvement is that monitoring processes take the responses from a site that tells us when a limit is received, started and eventually completed. This data is then compared to the expected performance of the system to ensure the fleet is not just responding with data, but that the qualitative assessment shows the data is accurate and within tolerance of acceptable operational bounds.

Another key measure is the extent to which customers inverters correctly adhered to the published flexible export limits. Analysis of device monitoring data indicated that flexible export limits were adhered to for more than 99.97% of 5-minute intervals.

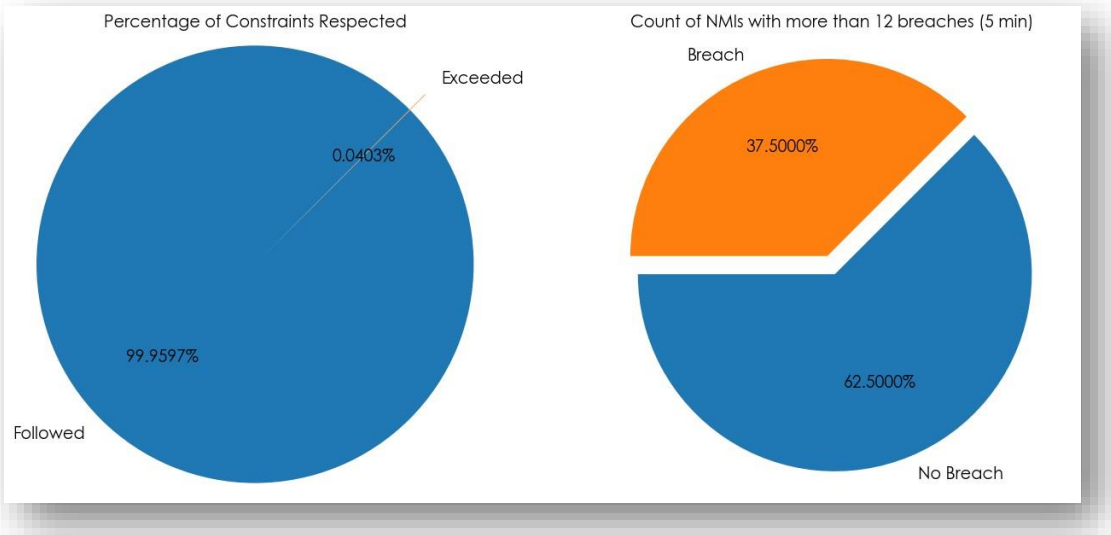
Approximately 15% of sites experience spurious export limit breaches greater than 250W. Almost all of these breaches were the result of measurement averaging windows not perfectly aligning with the device polling for export limits so are not cause for concern.

Figure 34: Constraint Responses

4.3.1.2 AusNet

Overall, most export limits have been followed by the system except for a single customer with an installation that appears to be working incorrectly. Including this customer in the data, the percentage of export limits that were exceeded is 1.432 percent based on 5-minute monitoring data. Excluding this customer, the average percentage of exceedance is 0.0403%. Examining this customer-by-customer shows that most installations respect issued export limits with few customers contributing to this figure, likely due to the communications connections at each customer site. These statistics have been evaluated for every 5-minute period since the start of the trial and a breach defined as a deviation of more than 250W (exceedance) of an issued operating envelope.

Figure 35: Export limit breaches



The count of NMIs with more than 12 breaches shows that most of the fleet are reliable, with most breaches spread randomly across several days rather than in sequence at a particular time. On average, the degree to which a constraint has not been respected is approximately 44W excluding the customer with system issues, however there are some systems which have far exceeded this value in any given 5-minute period.

There are several service objectives that could be defined as part of the project such as overall system latency, successful calculation and delivery of the operating envelopes, responses to emergency controls, and how the system responds to a system black event. In day-to-day operation managing the network, the overall system has proved reliable. Notably however, meeting a number of these services objectives will have a dependency on external infrastructure – specifically communications media such as infrastructure provider's backbone and local WAN networks, the customer internet connection, and the customer networking equipment (Router, Ethernet, and WiFi etc). In cases where an extended outage has occurred, it is possible that the telecommunications network may not be available as soon as power has been restored and therefore careful setting of any default limits is very important to having defined behaviour of PV inverters in this instance.

4.4 Research question 4: What is the scalability of the solution across the NEM/WEM?

4.4.1 SA Power Networks and AusNet

The scalability of Flexible Exports depends on a variety of factors, including the regulatory environment, the availability of technology solutions, and the necessity for electricity network operators to implement these solutions.

During the trial, the limited compatible equipment was a barrier to customer uptake, although this has improved significantly since the start of the trial. A nationally consistent framework, formalisation of IEEE2030.5 CSIP-AUS as AS HB 218:2023 along with jurisdictional mandates (like in South Australia, Queensland and soon Victoria) should give OEMs the technical and financial certainty to develop compatible systems. With mandates upcoming across Australia, it is crucial that this is addressed to ensure customer's technology choices are not limited. The national framework should address:

- Standards (AS HB 218:2023)
- System testing and certification
- Installer training
- National PKI arrangement

Additionally, networks across the NEM/WEM have differing levels of visibility of their networks and each DNSP needs to have a sufficient range of network data to safely determine flexible export limits across a network of customers, combining SCADA, AMI and other monitoring systems. With AusNet having high visibility through AMI and SA Power Networks comparatively low visibility, this shows that the solution are beneficial in both situations.

DNSP's will need to uplift their customer service offerings and systems to support Flexible Exports. In some instances, this could be achieved within customer or installer accessible portals that DNSP's may already have available, allowing first response and basic troubleshooting functions to be readily performed by the customer or installer.

At the time of writing the report, the regulatory environment driving Flexible Exports enablement is rapidly progressing. Nationally, there is significant regulatory and policy reform underway to unlock more value from consumer energy resources (CER). The SA Government has prescribed Dynamic Exports requirements mandating flexible export capability utilizing CSIP-AUS for all installations from 1 July 2023. The roll-out of Flexible Exports nationally will be dependent on

future national and state-based policy decisions, but most jurisdictions are progressing at pace. The Flexible Exports Trial has been extremely valuable in informing responses to policy reviews and evidence gained throughout the trial has leveraged key learnings from the AusNet and SA Power Networks approach to Flexible Exports. Some of the recent and current reviews include:

- **AER's Flexible Exports regulatory framework review**: This review intended to identify and clarify regulatory arrangements to enable the efficient implementation and uptake of flexible export limits. The final response to the flexible export limits issues paper consultation was released in July 2023.
- **AEMC CER technical standards review**: Recommends actions on the whole sector for ensuring CER is compliant with technical standards and able to be integrated into the network efficiently. AusNet and SA Power Network's participation with Trial, and our engagement with other DNSPs has put us in good position to make sure we're not going in a materially different direction to others. A draft decision has been published and our final response has been informed by works already underway to operationalise Flexible Exports at AusNet and SA Power Networks.
- **AER's review of zero export limits:** This was an update to the connection guideline to increase transparency around zero export limits. This was finalised in March 2023 and sets out exceptional circumstances under which networks can apply zero limits. One of the decisions is that if the business can offer Flexible Exports instead of a zero limit, they must offer it to the customer (from 1 July 2026).

Specific to Victoria:

- **DEECA DER/CER consumer protections review:** Ensuring Victorian customer protections framework is fit for purpose with growing DER/CER. Expecting a government update in December 2023 about potential reforms to consumer protections.
- **DEECA voltage management review:** To ensure the voltage management framework delivers customer benefits in the long term. Flexible Exports was just one of the dynamic and innovative solutions to better optimise the network and voltages, put forward by AusNet. The directions paper published in June 2023 provides Victorian Government's eight recommendations for policy and regulatory changes, targeting at improving customer outcomes related to voltage performance.
- **DEECA Consultation on Emergency Backstop Mechanism for Victoria:** In June 2023 DEECA released a consultation paper on Victoria's Emergency Backstop Mechanism for rooftop solar systems less than or equal to 200 kW to be implemented July 2024. The emergency backstop will mandate capabilities to remotely curtail new and replacement solar systems as a last resort to maintain minimum system load (MSL) and protect Victoria's system security using CSIP-AUS.

4.5 Research question 5: How much would it cost (scope) another distribution network to implement the capabilities required to support Flexible Exports?

4.5.1 SA Power Networks

Some components of the trial approach would not apply to another distribution network looking to implement the capabilities required to support Flexible Exports, whereas some will be directly applicable. This section will explore both.

Once off costs are those which should not need to be repeated by other distribution networks. Upfront costs include the initial costs associated with building the capability. Finally, ongoing costs are those which are incurred in operation of the service.

Some of these costs, especially those related to systems, will vary greatly between implementations where different architectures, suppliers etc are used.

4.5.1.1 Once off costs

Due to the emergent nature of the solution, there were several components to the delivery of the trial that are not required to be repeated by other DNSPs looking to implement a Flexible Export offering.

Standardisation of communications interfaces was a key early milestone for the project, which included a draft of CSIP-AUS which formed the basis of the document now formalised as Standards Australia Handbook 218:2023. This is now a published and tested guide for interoperability between a network and DER that it hosts that can be leveraged across Australia.

Testing of these interfaces and relevant device responses was also undertaken prior to the release of the Flexible Exports service. Learnings and documentation from this process in the trial was incorporated into the process used to implement the Dynamic Exports Regulations in South Australia. This supported the certification of over 95% of the solar inverter market share in South Australia, and should pave the way for adoption in other jurisdictions looking to leverage the capabilities in CSIP-AUS.

4.5.1.2 Upfront costs

Developing the customer offer, building systems and engagement with customers and industry comprise the major costs associated with establishing a Flexible Exports service.

Developing the customer offer includes the network modelling and forecasting to determine the service parameters included in the offer received by the customer. For SA Power Networks, this was an export limit between 1.5 and 10kW per phase, with 10kW being the limit for most of the time.

Building the systems to support the Flexible Exports service is the largest component of the upfront costs. Similarly, when procuring a product from a third party, there will be an upfront development cost for initial deployment. Some components of the solution, such as a LV visibility platform or a DER register, have their own benefits and use cases outside of supporting Flexible Exports and may already be present in a Distribution Network's systems.

Finally, engagement with customers and industry is a crucial part of establishing a new connection option and smoothly transitioning the capability into industry. As illustrated throughout the report, there have been many learnings from the perspective of a distribution network with this new interface to a customer. A similar uplift is required for the solar retailers and installers that need to successfully articulate the offer and install a compliant site. Website content in the form of instructions, infographic explainers, and animated videos, all helped to convey the message of change to industry.

The upfront costs incurred to establish these capabilities for SA Power Networks in the trial was in the order of $1.5m. Scaled development of the offer is funded under the LV Management Strategy program which has a budgeted $32m allocated in 2020-25 regulatory control period, including:

- LV visibility systems and data procurement
- Building and maintaining an LV network model (including LV switching)
- Establishment and maintenance of a DER register
- Dynamic export limit calculation

Of the $32m budgeted in the program, approximately $5.5m can be directly attributed to the Flexible Exports service offering.

4.5.1.3 Ongoing costs

Operational support and ongoing system costs are the two main cost factors for the ongoing support of the Flexible Exports service. SA Power Networks established a new role for the operational support of the network systems and to embed the new capability into the existing teams. An increase in support is also required from other business functions such as customer support, network planning and network operations.

Hosting, monitoring, and maintenance of the systems are also an ongoing cost. Building on cloud native applications can allow for a 'pay what you use' model with the system components, with the additional benefit of a per unit reduction in cost as you scale the systems. There is also an associated uplift in the management of these systems, leveraging existing support and maintenance functions from the IT teams.

The ongoing cost of supporting the Flexible Exports service offering escalates as the offering scales out with $3.8m allocated for the 2020-25 regulatory period. This cost includes many of the earlier mentioned components that have broader use outside of Flexible Exports such as a DER register and LV visibility, so the direct operating costs for Flexible Exports will be much lower in practice.

4.5.2 AusNet

At the time of writing, AusNet are less progressed in their scale up activities, and do not yet have a detailed budgetary estimate for implementing the Flexible Export BAU connection option. Key cost components identified include:

1. Upfront development costs and ongoing costs will be measured for the trial using public facing reset information.
2. Upfront and ongoing costs for transition to a full production system will be extrapolated from the measured data. These additional costs may comprise:
    - Costs to scale IT systems to deal with larger volumes of DER connections
    - Development of high availability systems (backups, geo-redundancy etc)
    - Enhancements to systems or process to support scale and address trial findings
    - Opex costs expected to be less than development costs

There are several key elements required for the successful implementation of a Flexible Exports solution. These can be grouped into several key areas:

- Visibility of the network to a sufficient level and at sufficient update rate to be able to generate a dynamic operating envelope or constraint that varies over time.
- A method of calculating the operational boundaries of the network at a sufficient refresh rate to meet the uptake rate goals.
- A platform that handles the data related to, and distribution of, the operating envelopes that links to external services such as the Utility Server.
- Management and oversight of the platforms and customer systems, including registration, onboarding processes and ongoing compliance.

The cost to each distribution network will differ based on foundational works delivered previously which may be able to be adopted to facilitate Flexible Exports implementation. For example, AusNet has leveraged existing capabilities, utilising AMI data for network visibility and calculation of operating envelopes, therefore there has been a minimal cost increase for this part of the overall solution as additional network monitoring hardware has not been necessary. AusNet's trial solution

has also leveraged existing Smart Networks analytics platform further managing total project costs. For DNSP's requiring the installation of additional hardware, or perhaps those utilising DPF or OPF power flow models, there are significant costs related to installation and data telemetry as well as computation power that present a barrier to offering an initial Flexible Exports or trial solution.

In early business case planning considering the implementation of Flexible Exports once the trial had concluded, AusNet considered a strawman model. Three different scenarios were presented all building off work already delivered and funded by AusNet. This had a range of options, including:

- A foundation option for providing a solution for trial customers and a limited number of additional customers, with budget estimations of ~$3m and an additional operational headcount of 2 FTE.
- An incremental growth solution, targeting the elimination of most export limits across the network, with budget estimates of ~$8m and an additional operational headcount of 5 FTE.
- A scaled option allowing for widespread DER penetration without a limit on customer numbers, with an initial budget estimate of +$40m and more than 10 new operational staff.

Also of note is the penetration of Flexible Exports systems as part of the trial or initial stages of a BAU rollout, where AusNet's statistical approximation method is appropriate for around <30% of customers. Beyond this, more advanced or sophisticated network models are required, increasing solution cost and complexity.

4.6 Research question 6: What are the costs and benefits for equipment manufacturers?

4.6.1.1 SA Power Networks and AusNet

SA Power Networks engaged with the industry collaboratively to develop the Flexible Exports offer. The engagement involved working with technical providers to assist in technology development as well as with Solar Retailers and Installers. This work is viewed as a strategic enabler and roadmap for future projects and initiatives that will benefit significantly from this partnering approach to joint interests and objectives.

Costs for original equipment manufacturers (OEMs) can currently be split into two parts: upfront/development costs and ongoing/operational costs. Fronius, one of the OEMs participating in the trial, indicated that there was a relatively small development cost for system design and implementation. However, the use of the Microsoft Azure cloud platform for sending export limits and receiving telemetry data incurs an ongoing cost.

That ongoing cost is quantified by the amount of data being sent. As the OEM's system grows, and more inverters are set up to communicate with it, the ongoing cost will also increase. The cloud-based systems can achieve economies of scale, as typically cloud providers such as Microsoft have tiered pricing models in which unit costs decrease with data volumes, however scaling up still imposes costs on the OEM.

Ongoing costs can be largely avoided by choosing a direct to device integration model where the inverter onsite is communicating directly to the Utility Server (with no OEM cloud platform between). Choice of communication model then becomes a tradeoff for OEMs – leveraging existing cloud platforms may present a faster and lower cost way to develop Flexible Exports capability but comes with ongoing costs. A direct integration may be slightly more challenging or costly to develop upfront but has no communications cost for the OEM. Cloud models may also be attractive for OEMs as they may present other opportunities such as customer visibility or provision of VPP services.

Specifically in Victoria with the existing network visibility via AMI metering (smart meters), AusNet are considering the exact telemetry requirements that are required specifically from the Flexible

Exports' devices. Whilst some of the datasets available are new to AusNet, not all available data may be required and in fact some datasets may be duplicates of data already available via AMI Smart Meters. Therefore, there is the potential for a reduction in the telemetry requirements that may be imposed on an OEM in jurisdictions with existing AMI Smart Meters.

OEMs who choose a cloud-based integration model must then determine how to recover costs. Although the OEM interacts with the installer, little to no direct interfacing with the customer is done. Increasing the sticker price of the inverter is one solution but is hard to estimate considering the ongoing costs for the service across the life of the inverter system.

The extensibility of the system is highly likely to prove to be an asset to OEMs in the future. Other initiatives such as Market Active Solar trial require export curtailment provides an opportunity for OEMs to charge retailers for this capability and recover costs.

Fronius has indicated that enabling more PV on the grid aligns with their motto "24 hours of sun" and is of benefit to them. Helping to increase the amount of renewable energy in the generation mix can be seen as both a positive environmental and social characteristic of the system.

4.7 Network benefits

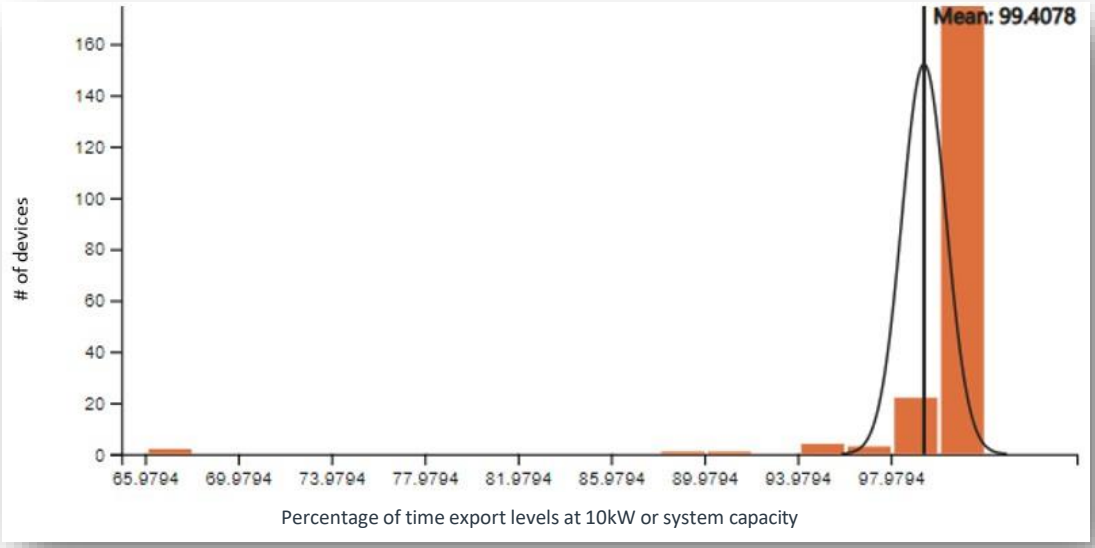
4.7.1 Research question 7: How much network capacity can be made available to PV customers compared to a reduced static limit, and under what network conditions are exports limited?

4.7.1.1 SA Power Networks

An enormous amount of network capacity is unlocked for use through Flexible Exports. Export limits as a result of the thermal ratings of SA Power Networks assets were never issued during the trial, with overvoltage acting as the sole driver of export limitation. The hypothesis at the start of the trial was that, on average, export levels would be at 10kW or inverter capacity for 98% of the time.

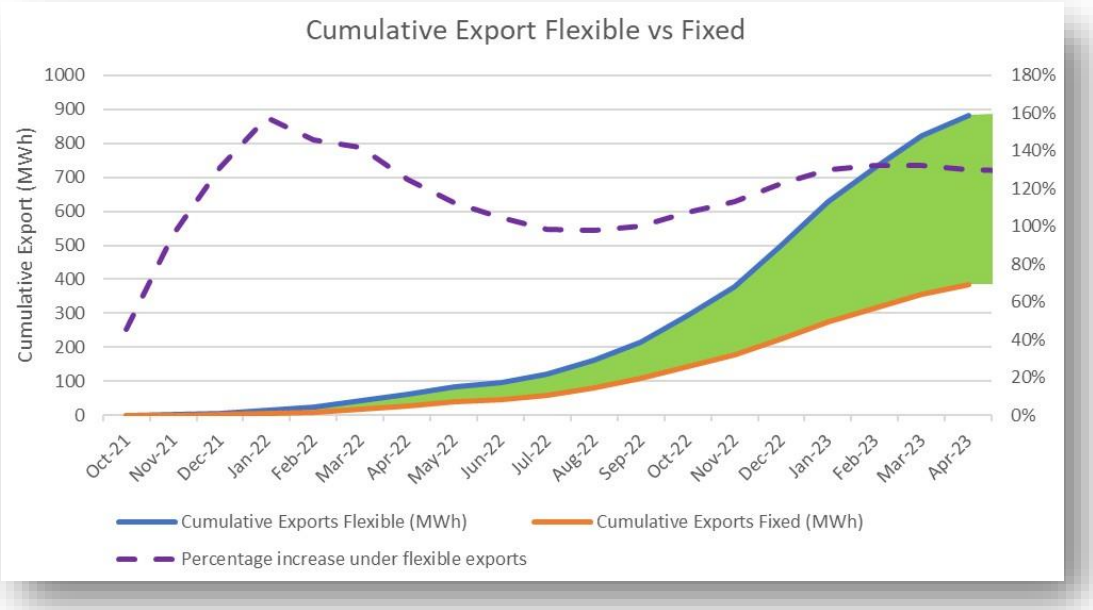
The statistical spread based on data collected in the trial (Figure 36) shows that, on average, devices were able to export at 10kW or their inverter capacity for 99.4% of the time, far exceeding the 98% target. Any curtailment on these devices was generally due to action taken by the Flexible Export system in the event of an emergency (such as an Heywood Interconnector outage), or days with exceptionally high voltages due to high PV output.

Figure 36: Statistical distribution of export limits



Outside of the rare times of network constraint, the Flexible Export option gives all customers greater access to renewable energy produced by CER. Figure 37 shows the total amount of energy released to the network by Flexible Exports customers, with Flexible Exports enabling a much larger energy export of renewable energy than if customers were under a fixed plan. The green shaded area represents the unlocked network capacity for South Australians under a flexible system and was ~500 MWh over the graphed timeframe.

Figure 37: Cumulative Energy Export by Flexible vs Fixed Systems



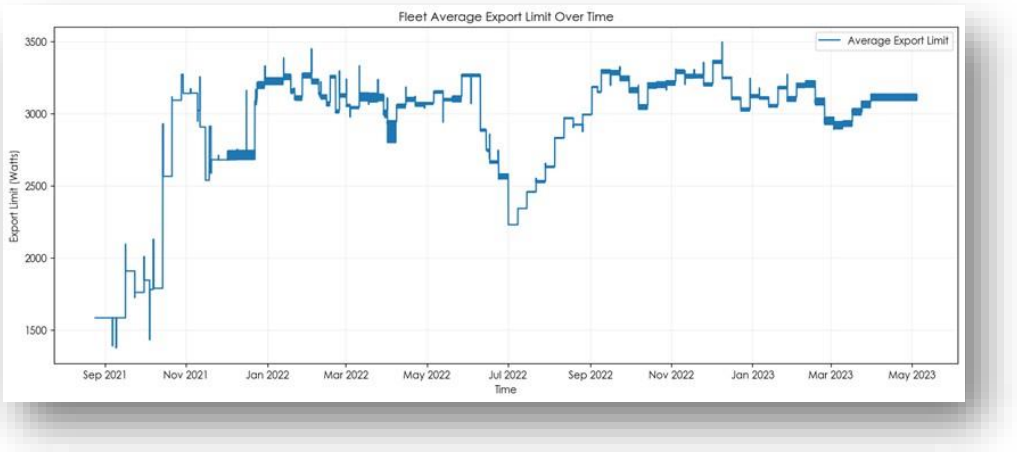
4.7.1.2 AusNet

On average, AusNet has enabled approximately 2.93kW of capacity for each Flexible Exports customer, calculated based on daylight hours irrespective of when the customers joined the trial and shown in the plot below. Most AusNet customers participating in the trial have inverter

capacities of 5kW or less, where 3kW of export offers the customers a significant incentive to participate in the Flexible Exports program compared to statically assigned zero export limits.

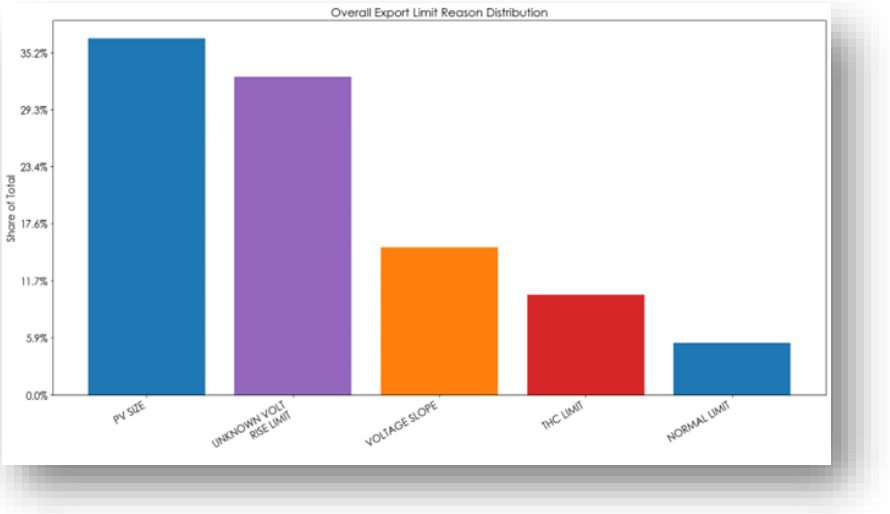
A new build of the export limit algorithm was deployed on the 7/6/22 changing some of the calculation methodology for customers with high solar self-consumption, which is partially responsible for the steep dip in assigned export limits observed around July 2022. This is compounded by the iterative nature of the algorithm which verifies the rise in voltage over time when increasing the export limit.

Figure 38: Fleet average export limit over time



Examining the status codes that are returned with each re-calculation of the export limits reveals that over the course of the trial, approximately 12% of assigned export limits have been due to a limit in the dynamically calculated hosting capacity of the substations. 36% of assigned limits have been at the customer's PV system size, effectively meaning they are not constrained (within AusNet's business rules limit of 5kW), with 33% of limits assigned part of the iterative nature of the algorithm, in between the hosting capacity limit and maximum permitted export of 5kW.

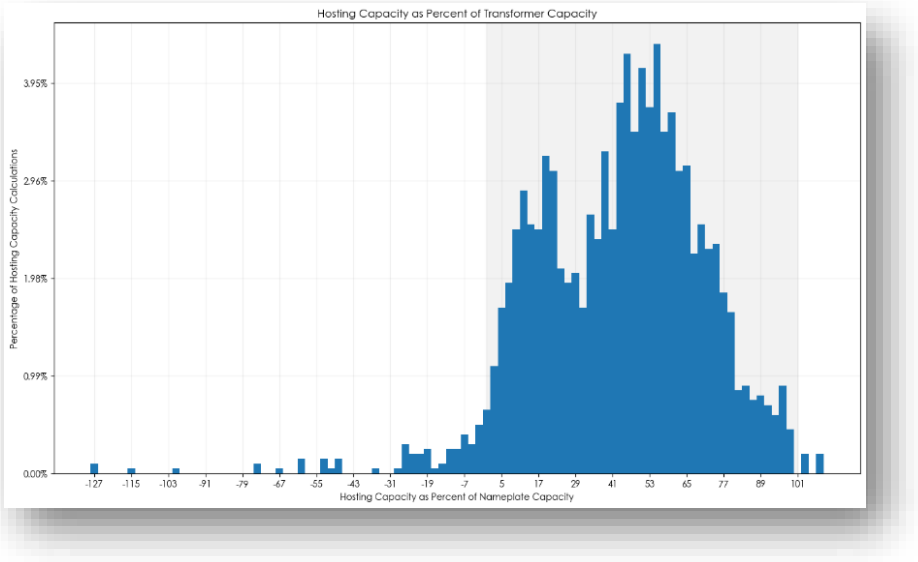
Figure 39: Overall export limit reason distribution



Examining when a customer is constrained – defined as when an export limit is assigned that is lower than the customer's inverter nameplate rating – shows that for AusNet, customers are constrained in some form approximately 75% of the time. Over the duration of the trial, a total of 154.62MWh of energy has been exported to the grid.

Transformer hosting capacity for each of the participating customers' substations is quite varied across the duration of the trial, showing that there are some substations with minimal hosting capacity available, and others with more capacity available. Most substations have a substantial variance in their hosting capacity over the duration of the trial.

Figure 40: AusNet Hosting capacity as % of Transformer capacity



4.7.2 Research question 8: Does the solution maintain the safe operational boundaries of the network?

4.7.2.1 SA Power Networks

SA Power Networks must maintain a voltage level of 230V +10% and -6% at each customers connection point, allowing an upper bound of 253 V. Additionally, as measured voltage readings are taken at the inverter, an additional 2% voltage rise is assumed to account for impedance in consumer mains. This means any reading <258V is considered to be within acceptable limits.

Voltage readings for every 5-minute period during daylight hours found that voltages were conformant more than 99.5% of the time.

In a simplistic sense, voltage readings can be classified into two categories:

- Readings above 258V where a constrained export limit has been issued – This implies that the system is not correctly recognising the need to constrain the exports of the system to manage the voltage problem.
- Readings below 258V where a constrained export limit has been issued – If the voltage of the NMI is below the upper bound, generally export limits should be unconstrained, as this would prevent the customer from exporting to their full capacity, limiting the unlocked network benefits of Flexible Exports. However, the constrained export limit may be keeping the voltage reading below 258V and therefore is not necessarily an indicator of problems within the system and could be indicating the opposite.

However, it is important to note that the constraint engine is based on an waterline or equal allocation approach at the distribution transformer rather than optimising at the customer. This means that a customer:

- May be overvoltage due to exports from another customer, so they may not need their export limits to be reduced

- May also be below the voltage threshold and still constrained to make sure they don't cause issues for other customers

This nuance is not considered in the analysis for simplicity.

Studying the voltage excursions can provide a good indication of the scenario that is taking place. Notice that during November of 2022, from the 13th to the 19th, the interconnector between South Australia and Victoria went offline and South Australia was unable to export extra energy interstate. The large number of voltage excursions during this time was a result of SA Power Networks enacting Enhanced Voltage Management (EVM) to keep demand above a threshold at the request of AEMO. This raises voltages at the zone substation in an effort to reduce the amount of generation from rooftop PV.

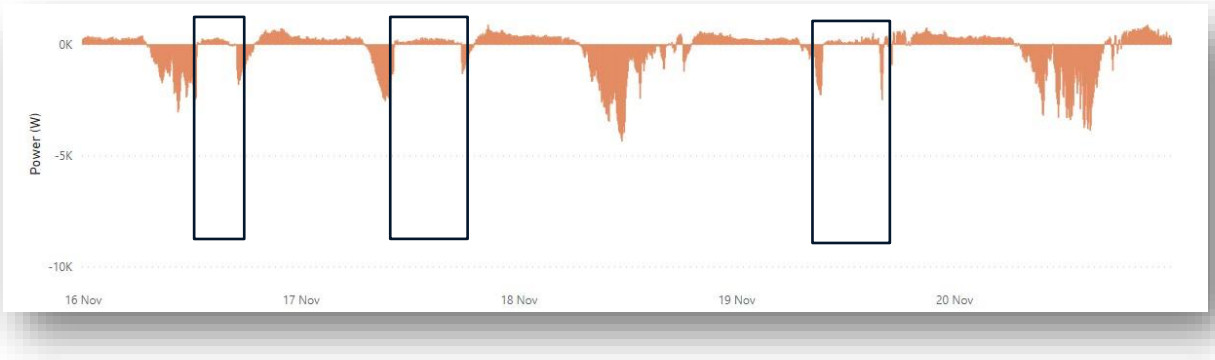
Figure 41: Voltage readings > 258 by excursion date

Date	# of voltage readings > 258 V
29/5/22	1
6/9/22	3
12/9/22	1
8/10/22	1
13/10/22	2
14/10/22	1
13/11/22	5
14/11/22	47
16/11/22	73
17/11/22	442
19/11/22	66
22/11/22	1
3/2/23	3
4/2/23	3
5/2/23	1
12/2/23	2
26/2/23	1

Outside of the period when the interconnector was offline, there were only 20 instances of voltage readings above 258V while systems were not export limited. This indicates the system is working as intended and manages to keep voltages below the desired threshold almost 100% of the time.

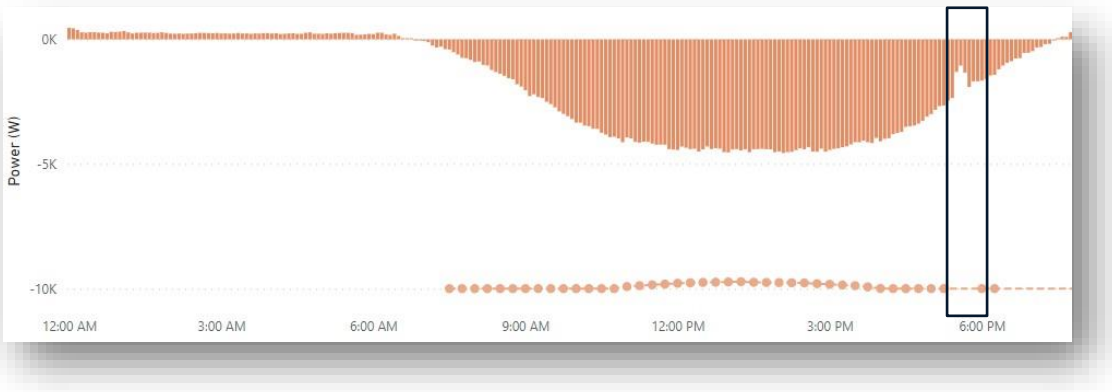
The interconnector outage also presented an opportunity to test the durability of the system during an emergency, where Flexible Exports systems had their export limits reduced to zero to support in the response. Figure 42 shows the average power output of all Flexible Export sites over time, and it can be noted that during the day on the 16th, 17th and 19th, export limits were set to 0. This shows that the user interface set up to manually change site was successfully able to limit sites, aiding in the emergency response for power system stability.

Figure 42: Devices responding to interconnector outage



On one occasion, the export limits engine had a short outage due to an erroneous weather reading. The system calculates export limits for up to an hour in the future, so about an hour after this error occurred, default controls were issued, setting any sites without a site override to a 1.5kW export limit. Figure 43 shows the average power reading from all devices on 23 December, supplemented by a dashed line showing the average constraint issued for a time interval.

Figure 43: System response to the constraint engine failure



The black box outlines the time approximately an hour after the constraint engine failure, when the issued export limits were no longer generated, and sites returned to their default export levels. When the transient error was resolved, the constraint engine successfully resumed issuing export limits. Note that some sites had override limits applied for testing purposes which results in an average greater than the default limit of 1.5kW. The root cause of the outage was identified and a fix put in place to prevent future interruptions.

In addition to this, the 'timeout' for customers with no export limits (due to internet outages or system disruptions) is being extended from 30-minutes to four hours for the BAU rollout and will be continually tweaked in collaboration with AEMO.

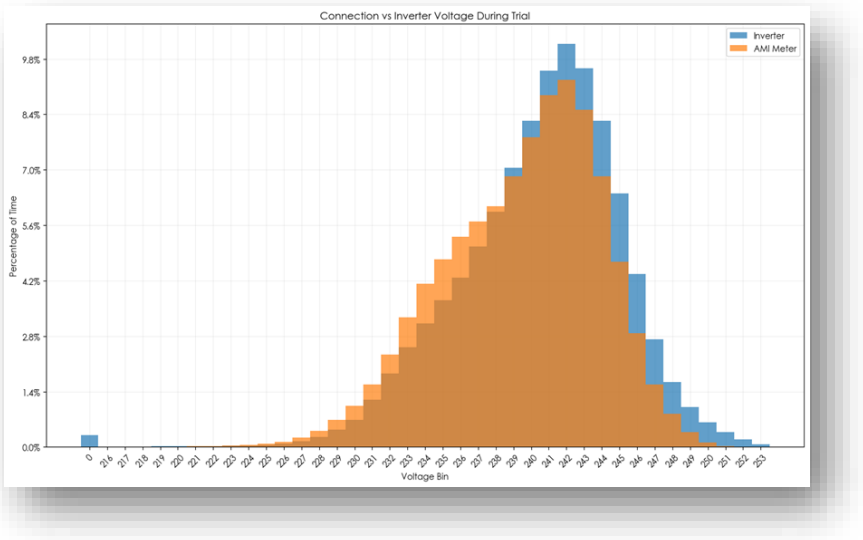
These emergency scenarios and responses demonstrate that the safe operational boundaries of the network are being maintained by the Flexible Exports solution.

4.7.2.2 AusNet

Based on the voltage data available from the inverters themselves, which is new information for most DNSPs, we can see that across the monitoring data collected in the trial that there have been 807 5-minute periods where 253V has been exceeded at the inverter terminals (blue trace below) –

approximately 0.05% of the time. This does not represent the voltages seen at the point of connection however, where EDC (Electricity Distribution Code) limits apply to the DNSP (orange trace below). This shows that there have not been any breaches of the EDC voltage limits for AusNet during the trial, indicating that the current hosting capacity algorithm could be less conservative.

Figure 44: Inverter voltage distribution during trial



Based on the monitoring data received, a voltage excursion of greater than 258V (observed at the inverter terminals) has only occurred 4 times during the trial for one customer, and all around the same time (2022-11-09).

Notable for AusNet is the update rate of the current Flexible Exports algorithm, which may result in impacts to the safe operational boundaries of the network if customers deviate significantly from their historical behaviour. This is because of the averaging and weekly update of the export profiles – if a customer makes a significant change in a short period of time, then there will be a delay between the impacts to the network and the effects becoming observable in the flexible export operating envelope calculation.

This even extends to customers that are not participating in the Flexible Exports trial, rather all network customers, as each customer on the network influences both the calculated hosting capacity as well as the local voltages. Therefore, it is important to have a reasonably accurate view and predictive estimate of expected demand and generation of all customers.

This is a limitation for the trial system, however, a more advanced deployment leveraging more real-time data, or even voltage feedback from inverters via the IEEE2030.5 monitoring interfaces could be incorporated to have a nearer to 'live' set of export limits. It is important to note a trade-off here between the complexity and running costs of the solution and the actual changing network conditions.

4.8 Solar industry

4.8.1 Research question 9: What are the new roles and responsibilities required to support Flexible Exports as a service?

4.8.1.1 SA Power Networks/AusNet

Table 8 outlines the identified roles and responsibilities from the trial and recommends a suitable body for responsibility moving forwards.

Table 8: Roles and Responsibilities

Role	Responsible in trial	Recommended Body for Responsibility
Product certification and listing	SA Power Networks	Clean Energy Council
Compliance hardware testing	SA Power Networks	Inverter test houses and cerifying bodies
Certificate Authority (SERCA)	SwitchDin	AEMO or a national PKI Management Authority
Commissioning	Installers	Installers, DNSPs as appropriate
Customer support	Installers/OEMs, DNSPs	All from trial involved depending on the issue
Communication aggregator	OEMs	OEMs and/or 3rd party aggregators

Product certification and listing: A centralised listing process will be the best solution for client certification. The centralised list will dovetail with existing inverter certification and listing scheme administered by the CEC, and so the client certification will be best managed in addition to this also by the CEC.

Compliance hardware testing: SA Power Networks is currently conducting CSIP-AUS client testing to support the SA Government Dynamic Export requirements. National harmonisation for this process means equipment manufacturers only need to complete the process once for Australia, removing significant barriers for other jurisdictions. It is anticipated that independent inverter test facilities that currently undertake AS4777 testing are best placed to take on this role.

Certificate Authority (SERCA): While SA Power Networks intends to operate its own Certificate of Authority to cover immediate flexible export needs, it plans to transition to a national framework. The project believes AEMO is the most suitable entity to administer this process, given their current support for established units and their focus on energy market cybersecurity. ESB recommended that an Interim PKI Management Committee (PMC), stewarded by the Department of Climate Change, Energy, the Environment, and Water, be established to work on a national PKI framework until a funded industry-led PKI Management Authority could be implemented.

Commissioning: Commissioning a site aligns with the installer's role during and after an installation.

Customer support: Retailers and installers form the first line of inquiry for customers. Issues can be escalated to OEMs and the DNSP if appropriate.

Communication aggregator: A communication aggregator facilitates communications with the Utility Server. OEMs can build their own aggregators or work with 3rd party aggregators which may

also provide other functionality such as VPP participation.

In April 2023, the Energy Security Board released a consultation draft of the Interoperability National CSIP-AUS 'Flexible Export Ready' Requirements. One of the key recommendations is for a nationally consistent approach to CSIP-AUS implementation by network businesses which includes:

- a national product certification and listing process,
- efficient level of alignment on installation certification processes, and
- uniform post-commissioning process.

Some of the draft recommendations present solutions to the roles and responsibilities required to support Flexible Exports, such as establishing a new accredited national test lab / testing scheme and use CEC for product listing services, but others will require even further resourcing from DNSPs to support. This includes that DNSPs may be required to provide a compulsory CEC-developed Flexible Exports training accreditation to local installers. Another example is that extra roles may be required to deliver operational monitoring of the continuing compliance of participating embedded generating units with dynamic connection agreements and the notification and rectification of customer non-compliance.

4.8.2 Research question 10: To what extent can solar installers understand the requirements of Flexible Exports service and install, commission, and support compatible systems?

4.8.2.1 SA Power Networks

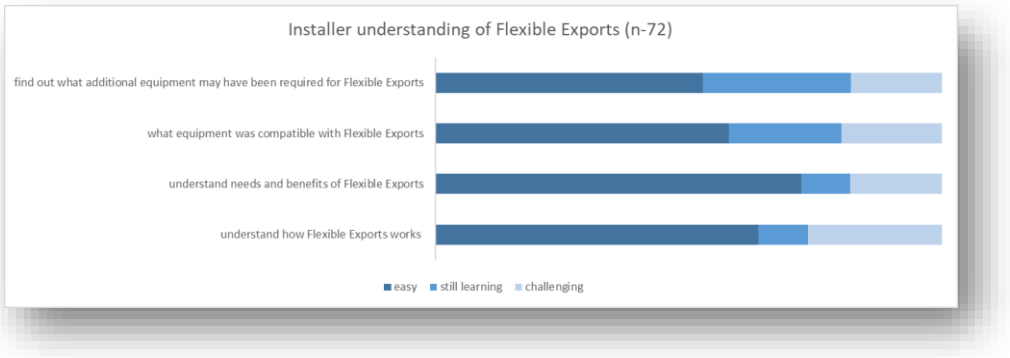
Given the delivery of Flexible Exports to mimic a standard service offering a lot of work was done to provide support to solar installers. An extensive plan of engagement activities included:

- Developing industry facing website where solar retailers and installers can get information about everything relating to Flexible Exports including what the offer is, compatible equipment available, the end-to-end process, how to successfully install a Flexible Exports site, and how to seek further support
- Development of animation, infographic, and diagrams to facilitate solar installers' engagement
- Continually engaging with solar industry through a range of working and reference groups
- Providing regular communications including Notice to Industry, newsletters, direct emails and SMS, proactive phone calls, free industry webinars to solar retailers and installers.
- Developing and providing free installer training courses in partnership with Clean Energy Council and Smart Energy Council (three in total, each with 30 CPD points)
- Undertaking a survey of solar retailers and installers

A survey was conducted with solar installers in South Australia. Out of 100 respondents, 72% of respondents indicated that they knew about Flexible Exports. Over half of respondents indicated that they knew a fair amount (32%) and a lot (24%). 16% indicated that they haven't heard of it; while 12% said they knew nothing more than the name.

Further information about ease of understanding Flexible Exports on how it works; the needs and benefits; what equipment was compatible; and additional equipment required can be seen in Figure 45.

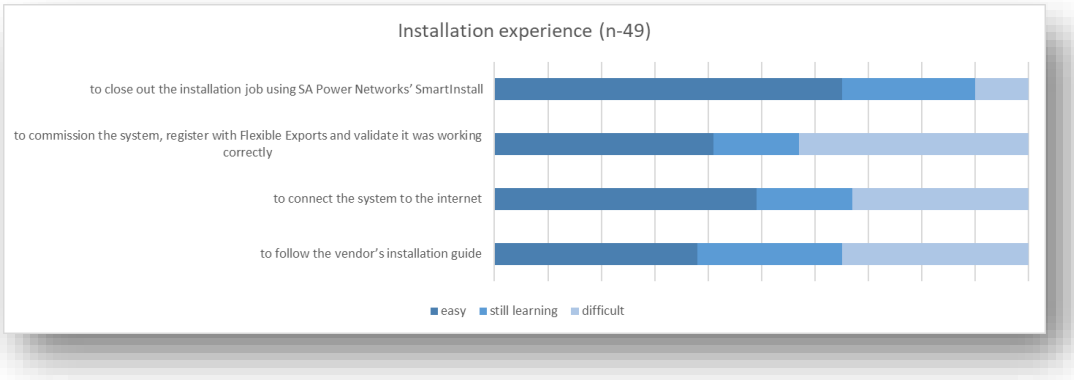
Figure 45: Installer understanding of Flexible Exports



Comments were made about the existing installation challenges and a desire was expressed for more variety of quality compatible equipment that is easier to install. From solar retailer's perspective, it was difficult to find compatible equipment that may not have been in their product suite, and that a payback period may be longer whether they choose Flexible or Fixed exports, while there is a lack of diverse range of compatible equipment. This is a trial specific challenge that has been resolved with the BAU rollout.

Of respondents who indicated that they are aware of Flexible Exports (n=72), they were asked how many Flexible Exports sites they have personally installed. 68.1% (n=49) indicated that they have experience in installing Flexible Exports. Further insights about the installation experience are seen in Figure 46.

Figure 46: Installer installation experience



Respondents were asked to provide reasons for the above answers. The general sentiments expressed were that there were some difficulties associated with installation and commissioning of trial hardware, affecting customer experiences negatively. Installers sought a step-by-step guide.

Beyond electrical installation of equipment, installers must connect the system to the internet, commission and troubleshoot systems. In the trial, SA Power Networks worked with the solar industry reference group (SIRG) to identify a process preferable for installers, talk about these results and then summaries.

Feedback from the SIRG also indicated that suitable support for OEMs was necessary, and clearly showed that ensuring adequate training for both installers and OEMs was a priority. SA Power Networks focuses on this feedback and implementations of trainings as an "industry uplift". The Droplet installation process is published on SwitchDin's LMS and website. The installer training/accreditation program has been set up in a way that covers all the steps from powering up

a Droplet to finally configuring the Flexible Exports controller for a unit. An installer must complete this training in order to gain access permissions for installation.

Increased availability of native compatible equipment will be closely aligned to the current commissioning process followed by installers, thus creating an easier transition to Flexible Exports for installers.

4.8.2.2 AusNet

With the growth of solar penetration, solar installations have become more complex. Compared to just a few years ago, installers must now be familiar with a wider range of technologies, including battery storage, smart inverters, and internet-connected monitoring systems. They must also be knowledgeable about network rules – often multiple different rules across multiple different distribution networks, depending on the territories they operate in – and installation regulations and safety standards. Staying up to date with industry developments requires ongoing training and education. Training and certification programs for solar installers have become more widespread and accessible and this has helped to ensure installers have the necessary skills and knowledge to install solar PV systems safely and effectively. However, Flexible Exports is a step change in solar technology which requires further upskilling specific to the strategy.

AusNet found it especially difficult to engage installers delivering training in a small-scale trial situation and using trial technology. AusNet are just one of five distribution networks operating in Victoria and many solar installers/retailers will work across more than one network's territory – this made cut-through with reaching this audience even more difficult just for the purposes of Trial technology upskilling.

The installers who did participate Flexible Exports trial installations found that on their first time doing a Flexible Exports installation, the final step of connecting the Droplet device to the inverter/internet and then commissioning the Droplet to the AusNet server could double the time required on site for an installation. Subsequent installations were a lot easier to complete but often installers did not undertake multiple installations.

Most Victorian installers adopted a wait-and-see approach to the trial until there is a clear financial incentive for them to install Flexible Exports devices and/or the technology evolves to become plug-and-play.

In some instances, customers interested in joining the Flexible Exports trial were unable to get their installer to undertake the installation. And in other instances, the installations were completed but without successfully commissioning the customer's inverter to the Flexible Exports platform.

The AusNet trial was supported with fully tested installation guidelines including instructions for who installers could contact for live support. In all instances when a customer signed a flexible connection agreement, their solar retailer was provided with the instructions. In the majority of cases, the solar retailer contact was not the solar installer, so there was no way for AusNet to confirm that the instructions were passed on to the installer. SwitchDin also developed an online certification for installers, but there was limited opportunity to ensure that this information was provided to the solar installer from the solar retailer.

As regulations change around what can/must be installed in jurisdictions – and if/when there is alignment between the distributors – more training can be developed to continue to upskill the solar installer workforce specific to state and national requirements, e.g., CEC accredited training where installers receive CPD for attendance.

4.9 Additional insights beyond the research

4.9.1 SA Power Networks

4.9.1.1 Compliance

A key challenge in the move to smart, flexible resources is ensuring that installers can correctly install, register, and commission devices in a compliant manner. Significant work was done in the trial to develop and provide simple training and support guides for installers. Even with this in place, there was effort from SA Power Networks and OEMs to support installers through their first installation and provide troubleshooting support.

To manage DER compliance, including for Flexible Exports scale, SA Power Networks have introduced an automatic DER compliance program described in Section 5: Future work.

4.9.1.2 Interoperability

One assumption made during the design of the project, is that the technology built for CSIP-AUS would be made easier due to existing developments in California through the Rule 21 mandate that enforced compliance to CSIP, the document from which CSIP-AUS was developed.

Upon initial testing of the multiple clients involved with the utility servers, it was apparent that existing test tools were not sufficient to achieve interoperability. Significant integration testing of all components was required to achieve communications.

Building on this lesson, SA Power Networks have successfully employed a development and integration server as the certification tool for the Dynamic Exports requirements. This connects the client with a live server implementation, rather than a test harness, from the start of the process. This approach allowed for interoperability issues to be ironed out early in the process, rather than at the end.

4.9.1.3 Project Delivery Design

The project has permanently changed the way SA Power Networks will deliver this kind of project. The team spent a lot of time planning for success, considering delivery of technical build, launch, partnering with internal business and all of industry. Starting with a very clear vision of what success would look like from different perspectives, including customer and installer experience, external technology and regulation, decisions were made based on outcomes and principles. A lot of work was done to consider how all project components fit together and the approach was iterative and flexible. A lot of time in the project team was spent to monitor progress, stakeholder and partner risks, technology, and regulatory risk, and all was managed by adapting the approach over time.

The work to develop an approach to include the business-as-usual teams from SA Power Networks in the early stages of development instead of a project team working in isolation. This required business areas to provide a subject matter expert to work as conduit for information and the development of business process with their respective teams. The development of new roles included a customer and installer facing team within the customer and community department and a Distributed Energy Systems Engineer within the Network department for the technical operations required for the service. This has enabled a smooth transition to business as usual because the operational teams have been involved from the initial stages.

4.9.1.4 Communications reliant on retailers and installers

We learnt that it is important to work more closely with solar retailers and installers to ensure information to customers is effective and accurate giving the full story of what is available and the benefits. Installers have requested additional information that they can share which will enhance the knowledge of the benefits achieved through Flexible Exports by area.

The surveys that Newgate carried out highlight this. “With suppliers providing unrealistic information, Flexible Exports may not have been explained correctly, i.e., positioned as a restriction rather than a way to generate more exports.” – Newgate qualitative report

4.9.2 AusNet

4.9.2.1 Consistency in implementation

One of the major learnings in Victoria has been how difficult it is for just one distributor to deliver a small-scale offer. While many learnings were shared experiences between AusNet and SA Power Networks, there was a clear benefit to SA Power from being the sole distributor in SA and on delivering their Trial with a firm view towards future implementation under direction from the SA government. In Victoria, consistency with the four other Victorian distributors and open dialogue with the Victorian government will vastly benefit customers in the long run.

We have heard from industry participants – such as OEMs, CER installers and retailers, and all other customer agents – that consistency between distributors at a national level is critical to their cost management and ability to provide services at scale.

As mentioned in response to the research questions, AusNet supports seeking national consistency of roles and responsibilities where practical, for example, having a national technical regulator that facilitates accreditation of inverters with CSIP-Aus and national PKI framework. Where national consistency is impractical, for example, where there are differences in technical requirements between jurisdictions, where possible, we support consistency between Victorian distributors in processes that interact with installers, OEMs and customers’ agents.

Victorian distributors have already established a working group to address areas of possible consistency to streamline future requirements for industry participants and customers’ agents.

5 Future work

5.1 SA Power Networks

The journey from the concept of Flexible Exports to standard connection option has spanned over five years. The concept was first envisaged while developing solar integration strategies for the 2020-2025 regulatory proposal. SA Power Networks was successful in securing $32m in capex and $3.8m in OPEX allowance to implement Flexible Exports and other DER integration initiatives over the period.

Implementation began immediately after the initial business case was submitted with the Advanced VPP Grid Integration ARENA funded trial. This project successfully demonstrated the publication of flexible export limits to the Tesla SA VPP, effectively doubling the capacity of the 1000 battery VPP from 5kW to 10kW at certain times.

This was soon followed by the Flexible Exports for Solar PV project which aimed to take the technical concept developed with the Tesla VPP to develop the first customer facing Flexible Exports offer for solar customers. In parallel to this project, CSIP-AUS implementation guide was developed by the DER API Technical Working Group to support the business-as-usual scale out.

Development of Flexible Exports has been led by detailed and holistic strategy and planning which anchored decision making to core objectives including:

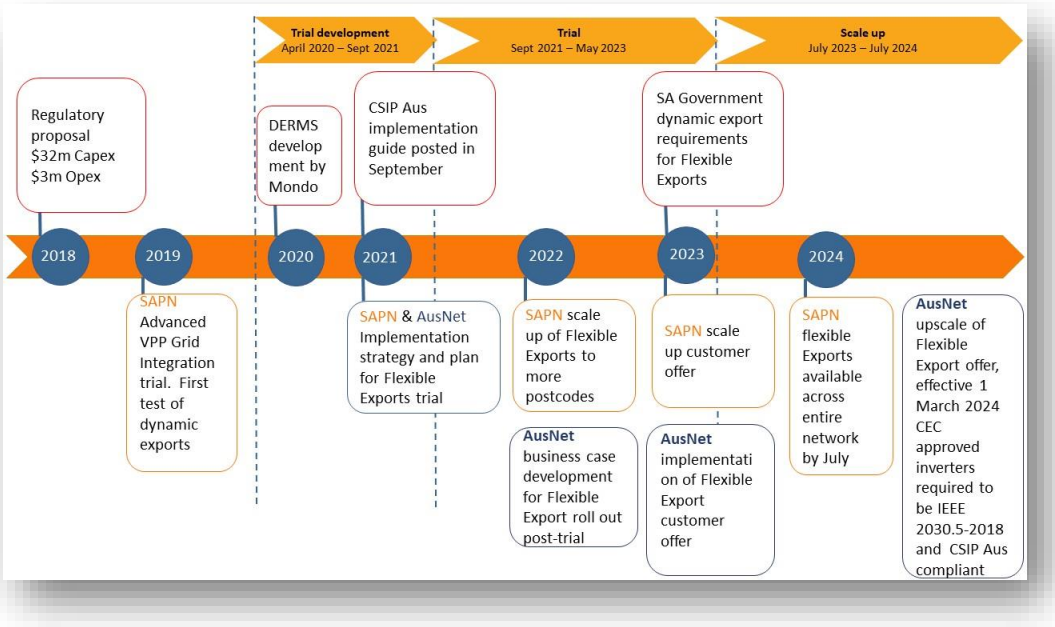
- A focus on end-to-end customer and installer experience
- Modelling an approach that could be deployed nationally
- Leveraging agile development principles to learn and adapt on the journey

Preparation for the business-as-usual launch of Flexible Exports was executed within a multidisciplinary program of works that aimed to deliver on this strategy. The launch was supported

by SA Government Regulations which required all new systems installed from 1 July to have Flexible Exports capability, resulting in significant support from equipment manufacturers.

A timeline showing the key steps on this journey can be found in Figure 47. Key steps on this journey, plus other key future activities are further explored in this section.

Figure 47: Future work roadmap



5.1.1 Dynamic export requirements

The Government of South Australia brought new dynamic export regulations into effect on 1 July 2023. These regulations require all new solar system installation and upgrades to be 'dynamic exports capable'. A system is considered dynamic exports capable if it has a CSIP-AUS compliant communications pathway and is configured to manage site-wide export limits. Any dynamic exports capable system can be enrolled in a Flexible Exports connection offer from SA Power Networks if available.

The SA Government Office of the Technical Regulator (OTR) have developed two technical guidelines that outline the requirements for a site to be considered dynamic exports capable. Given no national certification for CSIP-AUS was available, and based on the experience gained in this trial, SA Power Networks was responsible for testing and certification to the dynamic exports' requirements. SwitchDin were contracted by SA Power Networks to deliver the cloud-based test tools to enable certification to occur.

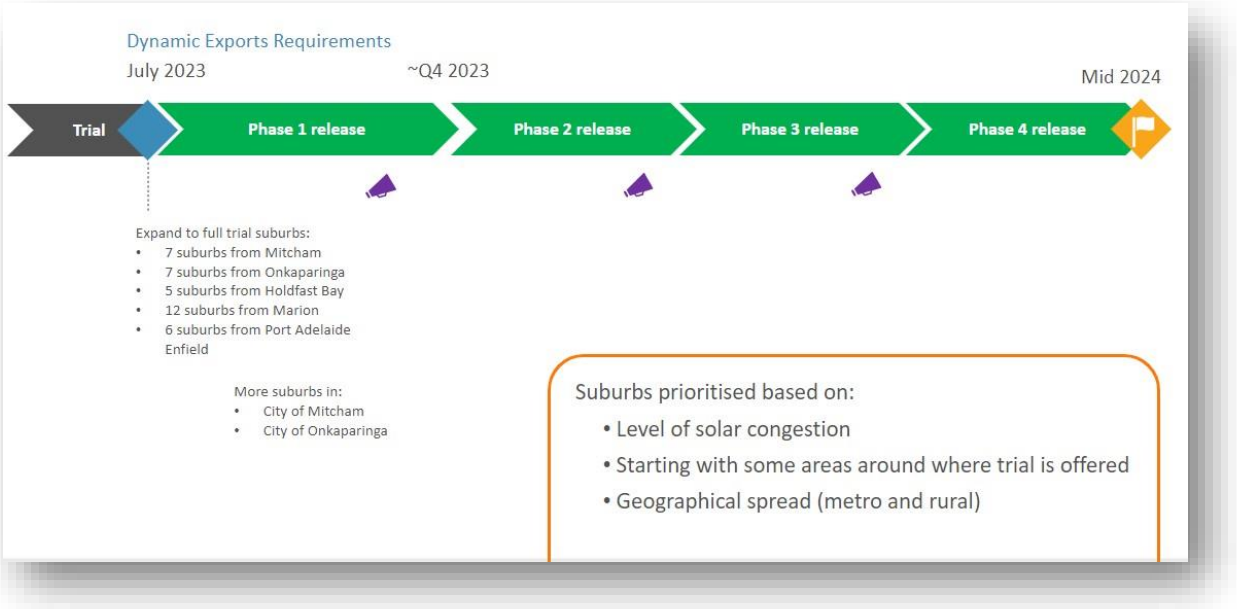
The program provided extensive development support to inverter manufacturers, with more than 95% by SA market share of inverters now certified. In addition to supporting the SA government requirements, the certification efforts have also paved the way for Flexible Exports to be adopted nation-wide.

5.1.2 Rollout of Flexible Exports offer

SA Power Networks have commenced the rollout of the Flexible Exports connection option to coincide with the introduction of the SA Government Dynamic Exports Regulations. The offer is being rolled out suburb by suburb across four phases to manage the industry and operational

impacts, and to ensure the DNSP and equipment manufacturer systems and support are keeping up with demand. The rollout will occur over 12-18 months with Flexible Exports to be available state-wide by July 2023.

Figure 48: Dynamic exports requirements



The scale out of the program has been backed by a program of works which began soon after commencement of the trial. The program is extensive and multi-disciplinary, including the following work streams:

- **Customer experience stream** which mapped the end-to-end customer and installer journey of Flexible Exports and has formed the basis of the design and web-based collateral.
- **Customer systems stream** further developed the capabilities within SmartApply and SmartInstall based on trial learnings. Some additional features developed include:
    - An advanced version of the ability to check if Flexible Exports is available at a specific address.
    - Visibility of indicative export levels for prospective Flexible Export customers. This information is based on historical data specific to the customer location and available on our website.
    - Onsite capability test to ensure installers can determine whether a site is functioning correctly prior to leaving site.
- **Internal technology stream** which further developed the systems responsible for calculating and publishing the flexible export limit. Majority of the focus was on enhancing the utility server and backend systems for robustness, scalability, and cyber security.
- **External technology stream** which developed the test and certification program to support manufacturers meet the dynamic export requirements. This included working

with SwitchDin to specify and guide development of a development and integration server and provide extensive integration and troubleshooting to manufacturers.

- **External stakeholder stream** which led the stakeholder engagement efforts with a strong focus on installer and equipment manufacturer engagement. This stream included development of many industry communications artefacts, ran the Solar Industry Reference Group and surveys to elicit feedback on the approach and developed several online and in-person training courses for installers.
- **Internal change stream** which developed the support framework and processes and ran training to enable SA Power Networks to operate a seamless Flexible Exports connection option.

The offer was successfully launched on 1 July and uptake, operational performance and customer response are being closely monitored.

5.1.3 Compliance program

Consumer Energy Resource compliance has been an ongoing challenge for DNSPs across the country. Early compliance figures found that overall, 60% systems are correctly installed and configured, which has an impact for network and system security as well as limits the hosting capacity that DNSPs can make available to consumers.

Early efforts to raise awareness with, and educate, solar retailers and installers had some impact but did not shift the dial far enough. To that end, SA Power Networks have developed a comprehensive automated compliance process.

In the automated compliance process, solar retailers must ensure that more than 90% of the systems they have installed are compliant. If they are not able to achieve this, after three warnings spread one week apart, they will be blocked from applying for grid connection approval in SmartApply and therefore be unable to collect the STC rebate for the installation. This process is summarised in Figure 49.

Figure 49 SA Power Networks automatic compliance management process

Requirements that will contribute to the solar retailer's compliance percentage will be rolled out across several phases:

- **Phase 1 SmartInstall closeout** (May 2023) Installations must be correctly 'closed out' within SmartInstall to be considered compliant. This includes declaration of installed equipment, relevant settings, and serial number to facilitate remote disconnection.
- **Phase 2 Flexible Exports** (July 2023) Flexible Exports sites must be correctly registered and pass the capability test to be considered compliant.
- **Phase 3 Export limits** (TBD) Sites must be correctly adhering to fixed or flexible export limits to be considered compliant.
- **Phase 4 Volt-VAr** (TBD) Sites must have the correct volt-VAr settings applied per AS4777.2:2020 Region A to be considered compliant.

Compliance for phases 2 and 3 will be assessed through a combination of AMI and Flexible Exports data.

The current compliance rating has been made visible to solar retailers within SmartInstall so they can track their percentage over time.

When the compliance rating was first introduced only 16.5% of solar retailers had a compliance rating above 90%. In August 2023 this percentage improved to 84% due to the introduction of the first stage of the compliance management program. We expect that the continued development of the plan which entails including a wider range of non-compliance issues as well as consequences for sustained non-compliance will radically improve this percentage overtime.

5.1.4 Integration with market facing offers

In parallel to the introduction of Flexible Exports, energy retailers have been looking to introduce new retail offers that reward customers for curtailing solar during times when the wholesale price of energy is negative.

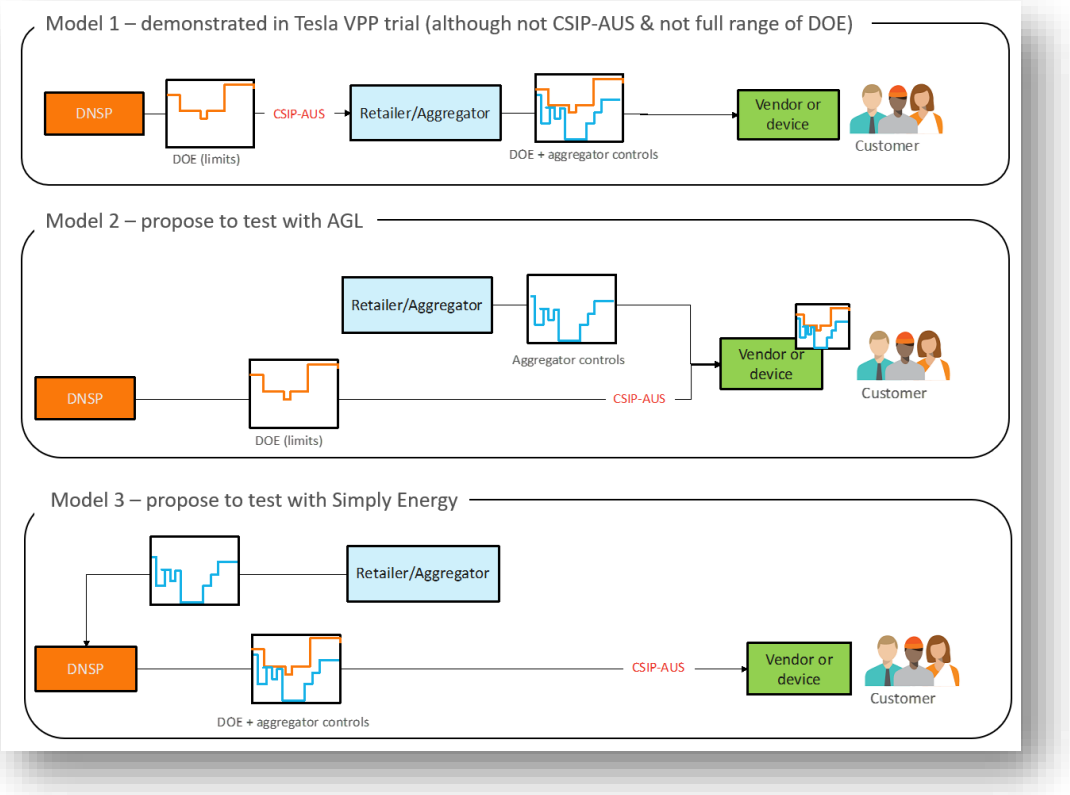
The integration of these retail offers and DNSP flexible connection agreements is a key opportunity for activating DER to manage network congestion and address energy oversupply in the broader market.

The ARENA funded Market Active Solar (MAS) Trial seeks to address this opportunity by testing two technical integration models which, in partnership with AGL and Simply Energy, will demonstrate how DNSP Flexible Export Limits (otherwise known as 'dynamic operating envelopes' (DOEs)) can act in concert with retailer-initiated schemes that actively manage the output of a customer's solar inverter in response to market price signals. These models are shown conceptually in Figure 50 , alongside a model previously tested with the Tesla VPP.

These models, alongside solar management retail offers from Simply Energy and AGL, will be tested through a 12-month field trial with 100 customers.

The trial will test consumer understanding and acceptance, inform future market design, and demonstrate pathways for retailers and DNSPs to collaborate to actively manage small-scale solar.

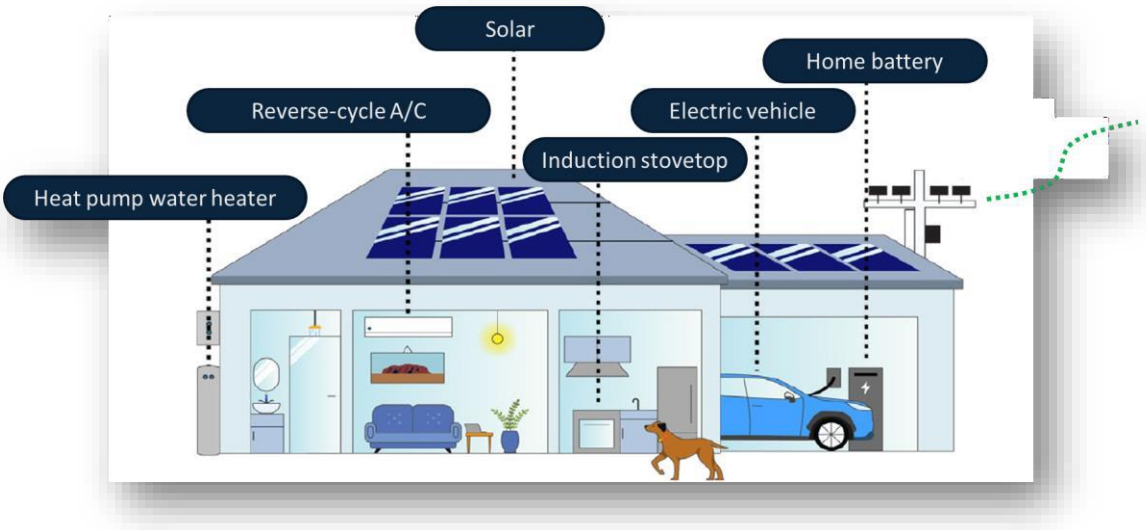
Figure 50: Integration architectures to support DNSP and retailer curtailment



5.1.5 Expansion to load-side DOEs

As households begin to 'electrify' to save money and decarbonise their homes, many new assets such as batter storage, electric hot water, electric heating and cooling and electric vehicles will be purchased and installed.

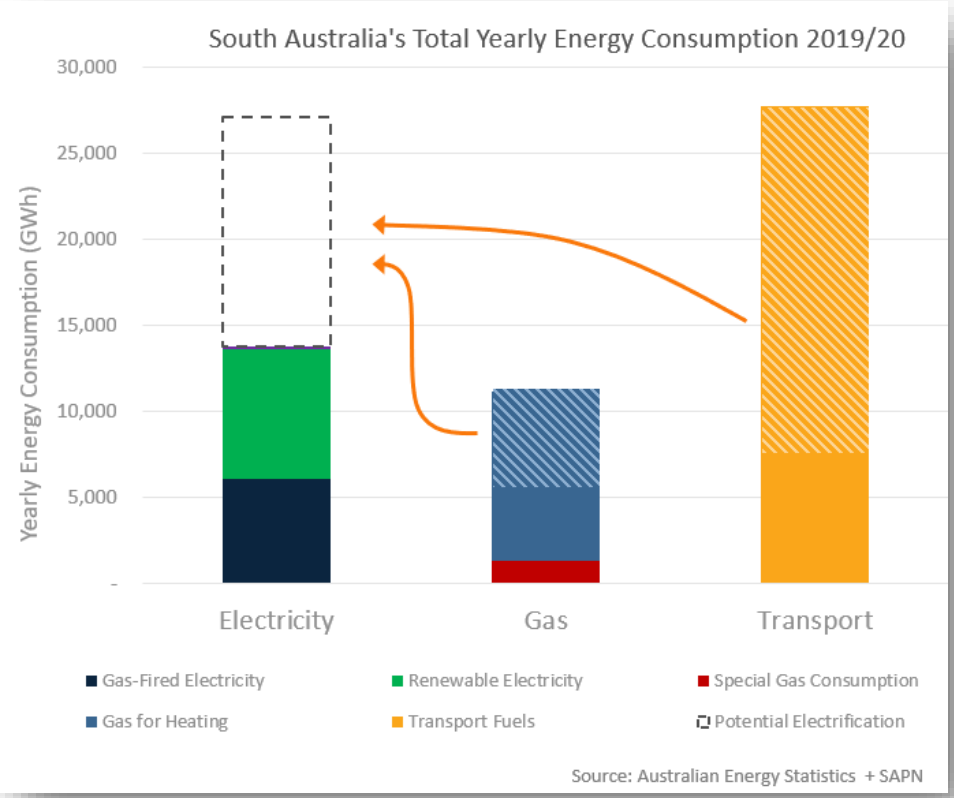
Figure 51: Smart home



These assets will result in the distribution network more than doubling the energy it transports to and between consumers. Without intervention, this could double the peak demand on the

network, driving billions of dollars of augmentation investment which consumers will pay for through their energy bills.

Figure 52: South Australia's total yearly energy consumption 2019/20



In much the same was as Flexible Exports is an efficient means to integrate solar, flexible connections for electrified smart homes could allow these new resources to be integrated into the system in a way that minimises cost for all energy customers. This is why SA Power Networks is seeking to develop more new flexible connection options for import and export over the coming years. This will effectively complete the Dynamic Operating Envelope by enabling flexibility for both load and generation.

To enable Home Energy Management Systems (HEMS) to optimise energy use for consumers and comply with a site-wide dynamic operating envelope, devices must support open communication and control interfaces. This is not the case today, so in developing these new offers, SA Power Networks intends to work with industry stakeholders to establish open interoperability requirements for appropriate devices. The systems built to support the flexible exports rollout have been designed to be extensible and scalable to support the generation and delivery of a whole of home DOE to all customers in South Australia.

5.2 AusNet

Over the course of the trial, AusNet have utilised learnings to input to significant policy reviews. The model implemented by the Trial has developed in line with where the regulations are heading, and this increased AusNet's confidence to fund an initial operationalising of the Flexible Exports offer in 2023.

AusNet aligned all activities to be able to launch our trial at the same time as SA Power Networks in September 2021. Since Victoria did not have the same regulatory drivers as South Australia, our timeline for operationalising Flexible Connection Agreements post-trial has deviated from SA Power Networks. There was a very strong commitment from AusNet to ensure that customers recruited to the trial did not have to revert to their fixed constrained export limit after the trial had concluded.

AusNet has been successful in creating keeping its systems functioning to transition these customers while the Flexible Connection Agreement (FCA) is further developed across 2023.

Major changes, all likely to be implemented in 2024, will now accelerate the potential scale up of Flexible Exports, including:

- Solar Victoria's CSIP-Aus mandatory compliance to participate in the solar PV rebate streams
- AER's Flexible Exports regulatory framework review supporting the introduction of Flexible Export MSO
- DEECA's implementation of an Emergency Backstop Mechanism in Victoria

The minimum system load (MSL) challenge has been growing over the years, and Australian Energy Market Operator (AEMO) estimates approximately 665MW of curtailment response will be needed by Victorian distribution networks by the 2024/2025 Summer/Spring period to securely manage the electricity system by maintaining a minimum synchronous generation. Approximately 27% of AusNet's customers have rooftop solar, and each year we reach new records of minimum demand on our network. Our current forecast estimate that at the current rate of solar rooftop take up, our network may reach zero demand on average during the day as early as 2024.

The Victorian Government will be introducing emergency backstop mechanism for new and replacement rooftop solar systems: for large systems (greater than 200 kW) by no later than January 2024, and for small and medium systems (200 kW and less) by no later than July 2024. The emergency backstop will mandate capabilities to remotely curtail new and replacement solar systems as a last resort to manage minimum system load emergencies and protect Victoria's system security.

DEECA has recommended the use CSIP-Aus as a backstop measure for systems below 200kV in alignment with Solar Victoria's published a Notice to Market 2023–24, requiring installed systems to implement the CSIP-Aus protocol effective 1 March 2024. Solar PV inverters must be listed on Clean Energy Council's Approved Inverter list as an Inverter with Software Communication Clients that is compliant to CSIP-AUS and IEEE 2030.5; to be 'dynamic export' capable to allow for the future implementation of dynamic export arrangements by Victorian distributors.

The backstop mechanism will provide some capacity for curtailment, but it will not be sufficient to address the required capacity for generation curtailment, or load increase, for several years. There is a strong case for networks to implement measures that reduce minimum demand risk and improve demand flexibility, rather than relying on the backstop mechanism.

AusNet is trialling initiatives to incentivise and manage CER on our network, in a way that manages both maximum and minimum demand risk. These include innovative trials such as Project EDGE, new tariff trials with solar-soak periods, including the Flexible Critical Peak Demand (CPD) and electric vehicle (EV) tariff trials, and use of grid-sale energy storage and microgrids.

Flexible Exports can be used to restrict exports on days of low demand, to reduce the need for AEMO to implement extreme backstop measures in the first place. With all new Victorian customers required to have CSIP-AUS inverters from July 2024, there are more opportunities to sign up customers on Flexible Exports and manage low demand days through exports management. While AusNet had been progressing with a measured approach to scaling up its Flexible Exports capacity in 2023-24 – in line with industry development and customer demand – the investment in systems, processes and supports needed for the implementation of MSL increases the potential scale up of our Flexible Exports implementation.

AusNet had been planning to launch initial flexible export offers to customers under a negotiated agreement. However, the AER has recently published the final response to 2022 consultation and has proposed that distributors may implement Flexible Exports on an opt-in basis under a Model Standing Offer, and lists priority actions to establish a Flexible Exports governance framework including:

- "Improving the provision of information to electricity consumers on flexible export limits to help build consumer awareness and trust
- Initiation of a rule change proposal to provide the AER with the appropriate head of powers to develop and publish a binding Export Limit Guideline governing methodologies for export capacity allocation and provision of information to consumers
- Development and publication of interim guidance on export limits, to establish expectations for the operation of both static and flexible export limits."[14]

These regulatory changes will further enable and accelerate AusNet's scale up of Flexible Exports offer.

Figure 53: AusNet Flexible Export roadmap

[14] Australian Energy Regulator, "Flexible Export Limits Final response and proposed actions", July 2023 https://www.aer.gov.au/system/files/Flexible%20Export%20limits%20Final%20Response%20-%20July%202023_1.pdf

Appendix: Glossary of Terms

Acronym	Description
AC	Alternating current
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
AMI	Advanced Metering Infrastructure
ANU	Australian National University's
API	Application Program interface
ARENA	Australian Renewable Energy Agency
AWS	Amazon Web Services
BAU	Business as usual
CEC	Clean Energy Council
CER	Customer Energy Resource
CPD	Continuous Professional Development
CSIP-AUS	Common Smart Inverter Profile Australia
DEECA	Department of Energy, Environment and Climate Action
DEIP	Distributed Energy Integration Program
DER	Distributed Energy Resource
DNSP	Distribution Network Service Provider
DOE	Dynamic Operating Envelopes
EDC	Electric Distribution Company
EOI	expression of interest
ESB	Emergency Switch Board
EVM	Enhanced Voltage Management
FCA	Flexible Connection Agreement
KVA	Kilo-volt-amperes – a term used for the rating of an electrical circuit. kVA is the product of the circuits maximum current and voltage rating
kW	Kilo watts. A kilowatt is 1000 watts
kWh	Kilo watt hour. A kilowatt-hour is a unit of energy, one kilowatt of power for one hour
LEG	Large Embedded Generation
LMS	Learner Management System
LV	Low voltage
MAS	Market Active Solar
MEG	Medium Embedded Generation
MQTT	Message Queuing Telemetry Transport
MSL	Minimum System Load
MWh	A megawatt hour (MWh) equals 1,000 kilowatts of electricity generated per hour
NEM	National Electricity Market
NMI	National Meter Identifier
OEM	Original Equipment Manufacturer
OPEX	Operational Expenditure

Acronym	Description
PKI	Public Key Infrastructure
PQ	Power Quality
PV	photovoltaic
SEG	Small Embedded Generation
SmartApply	SA Power Network's App where customers can submit applications to install solar
SmartInsights	SA Power Network's App where customers can monitor the performance of their solar
SmartInstall	SA Power Network's App where installers must close out installations and complete a capability test
SWER	Single-wire earth return (SWER) or single-wire ground return is a single-wire transmission line which supplies single-phase electric power from an electrical grid to remote areas
T&C's	Terms and Conditions
THC	Tactical Hosting Capacity
V	Volt
VPP	Virtual Power Plant
W	Watt
WEM	Wholesale Electricity Market

Appendix: Table of Figures