Demand Flexibility Platform

Knowledge Sharing Report 2

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Purpose

The purpose of this document is to provide a second update to the Australian Renewable Energy Agency (ARENA) and the industry regarding project progress and lessons learned to date on the Intellihub Demand Flexibility Platform Project.

Acknowledgements and Disclaimers

The Demand Flexibility Platform project is a collaboration between Intellihub and project partner GreenSync. Intellihub also collaborated with Evergen to develop a section of this report.

This project received funding from the ARENA as part of ARENA's Advancing Renewables Program.

The views expressed herein are not necessarily the views of the Australian Government. The Australian Government does not accept responsibility for any information or advice contained within this document.

Contents

Acronyms

Acronym	Description
ADMS	Advanced Distribution Management Systems
AEMO	Australian Energy Market Operator
AESCSF	Australian Energy Sector Cyber Security Framework
ARENA	Australian Renewable Energy Agency
API	Application Programming Interface
CER	Consumer Energy Resources
CSIP-Aus	Common Smart Inverter Profile – Australia
DER	Distributed Energy Resources
DERMS	Distributed Energy Resources Management System
EV	Electric Vehicles
LTE-Cat M	Long-Term Evolution Machine Type Communication
NMI	National Meter Identifier
OEM	Origin Equipment Manufacturer
PV	Photovoltaic
VPP	Virtual Power Plant

1 | Background

1.1 | Project Overview

Intellihub has launched a Demand Flexibility Platform (the Platform) targeting over 500 MW of aggregated load under control with over 100,000 customer devices enrolled (the Project). The Platform builds on the deX platform developed by GreenSync, and will target registration of hot water systems, solar inverters, batteries, electric vehicle (EV) chargers, and pool pumps over a two-year period.

The Project will allow Virtual Power Plant (VPP) operators, such as electricity retailers (retailers), and networks, and aggregators to enable flexible operations of Consumer Energy Resources (CER or Devices). VPP operators can integrate their VPP with multiple device types and manufacturers through a single integration, avoiding the costly development of systems, multiple device integrations, installation and additional communication systems.

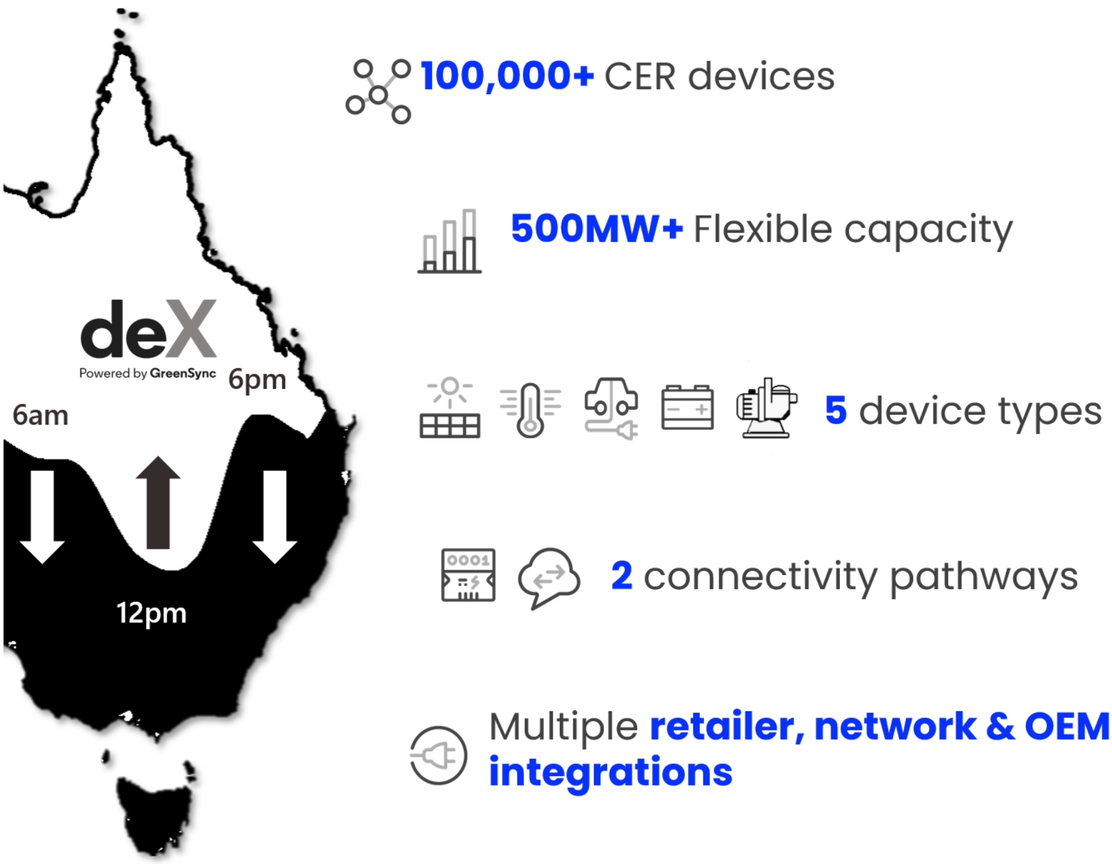

Figure 1 Overview of the Intellihub Demand Flexibility Platform

1.2 | The Flexible CER Opportunity

The recent growth in CER, including hot water systems, rooftop solar, battery storage, pool pumps, and EVs present the energy industry with both a significant challenge and an exciting opportunity. Uncoordinated, these CER contribute to stability and reliability challenges for the grid. However, when aggregated at sufficient volume through VPPs CER can provide much needed demand flexibility, unlocking benefits for retailers, networks and consumers.

Table 1 Benefits to consumers, electricity retailers, and networks

Consumers	Retailers	Networks
✓ Financial benefits from participating in VPPs ✓ Smaller carbon footprint by maximising off-peak or rooftop solar consumption ✓ Highly automated device operations with minimal customer involvement	✓ Reduction in wholesale energy costs ✓ Reduction in network costs ✓ Improved customer engagement	✓ Greater utilisation of network during off-peak hours ✓ Reduces voltage issues on network from excessive solar exports ✓ Defers costly network upgrades

The majority of CER currently lack flexibility, preventing the optimal use of the substantial energy they produce or consume. The industry faces challenges in aggregating these resources into VPPs on a large scale, due to the costs and complexities associated with integrating various device types and manufacturers. Achieving scalable CER connectivity and interoperability among consumer, grid, and market systems is essential for unlocking the full potential of CER and reducing negative impacts.

Figure 2 illustrates the estimated CER penetration for households in Australia, highlighting the expected growth in CER to 2030[1]. Solar PV and electric hot water systems are forecasted to have the highest penetration among households, followed by EV chargers and pool pumps.

[1] Source: AEMO 2023 Draft inputs, assumptions and scenarios report; 2022 AER State of the Energy Market report; ABS projected Australian households; EMI Data; Department of Agriculture, Water and the Environment report: Mordoor Intelligence; Intellihub materials;

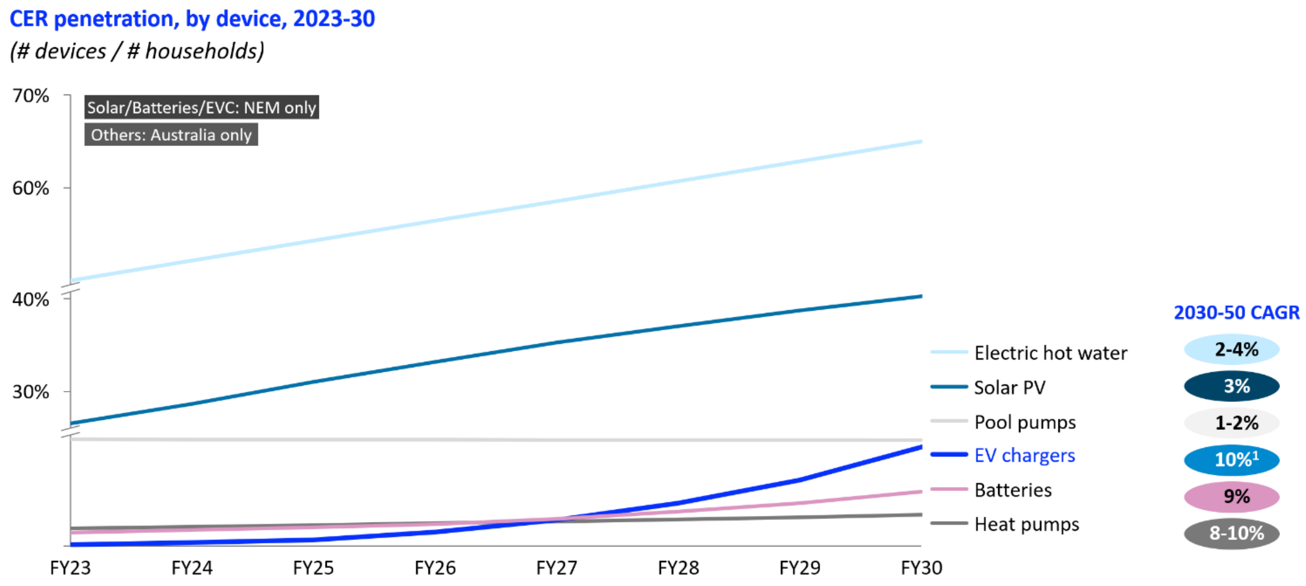

Figure 2 Opportunity sizing of flexible CER

2 | Solution Overview

The Intellihub Demand Flexibility Platform solves the challenge of integrating and managing multiple Original Equipment Manufacturers (OEMs) across a range of device type, enabling rapid scaling of VPP platforms. This platform integrates Intellihub's smart meter technology with GreenSync's CER registration and control software, deX to enable the realisation of a scalable CER registration and connectivity platform.

This platform will allow VPP operators, such as retailers, networks, and aggregators to integrate with multiple devices and device types through a single integration with one platform.

2.1 | deX

The deX platform has been developed by our technology partner GreenSync, and is the foundation of the Demand Flexibility Platform. deX is an Application Programming Interface (API) based platform that facilitates communication of CER instructions and CER data from multiple parties, reducing the costs and management overheads of integration, churn management and compliance.

The deX platform is complementary to other demand management solutions and is agnostic to technologies and vendors. Additionally, the platform is agnostic to CER type, brand and applications, which guarantees a universal technology pathway for connecting 'behind the meter' CER to any utility northbound platform used for CER orchestration and control.

With deX acting as a central integration point for OEMS, VPP aggregators, Advanced Distribution Management Systems (ADMS) and Distributed Energy Resource Management Systems (DERMS) it solves the 'many to many' problem for CER by reducing the number of point-to-point integrations, as illustrated in Figure 3 below.

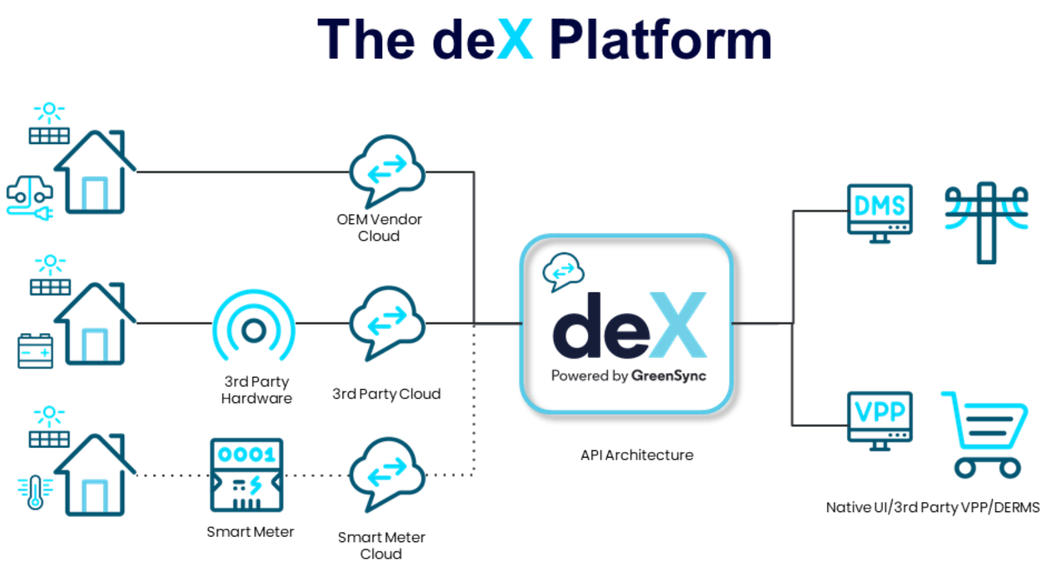

Figure 3 The deX platform

To achieve the above outcomes, a number of core capabilities have been implemented within the deX platform and APIs, including:

1. Registration and contracting CER (with a clear distinction between the two)
2. Non-exclusive interaction between a party (e.g. a retailer and network) and a CER, with visibility and coordination between parties
3. CER provision of both control and data information services
4. Enactment of dynamic/flexible export limits on CER by a network/system operator
5. A robust approach to control of CER
6. A complete solution for near real time telemetry provision
7. A system of record for all CER activity/behaviour to enable retrieval for reporting and analysis.

Compared to direct integrations with individual demand management providers or device manufacturers, the following benefits are realised when integrated with the deX platform:

- Immediate access to registered CER - Provides immediate access to an existing pool of thousands CER from trusted global brands without additional hardware.
- Reduces integration complexity - De-risks project delivery and reduces ongoing API maintenance by reducing the number of point-to-point integrations between OEMs, VPP platforms and DERMS systems.
- Designed for scale - deX has been designed to scale for millions of registered CER, with the platform already controlling hundreds of thousands of CER in real time.
- Universal CER Connect - Allows all CER to register in a standard format via customer Wi-Fi or via Intellihub's metering solution pathway. This also allows OEMs to maintain global approach to functions and avoid jurisdiction specific changes.
- CER registration and contracting - deX presents heterogeneous CER across device types and OEMs as homogeneous, enabling low friction customer authorisation for registration and contracting.
- Standardised control and telemetry - deX provides a unified and consistent approach for CER control and telemetry across multiple devices types and OEMs.

- Network friendly - Enables functionality for CER to operate with consideration for network defined limits. Provides future proofing of solution with respect to any future regulatory changes that enforces safe operation of CER (e.g. South Australia Smarter Homes and Flexible Exports regulations).

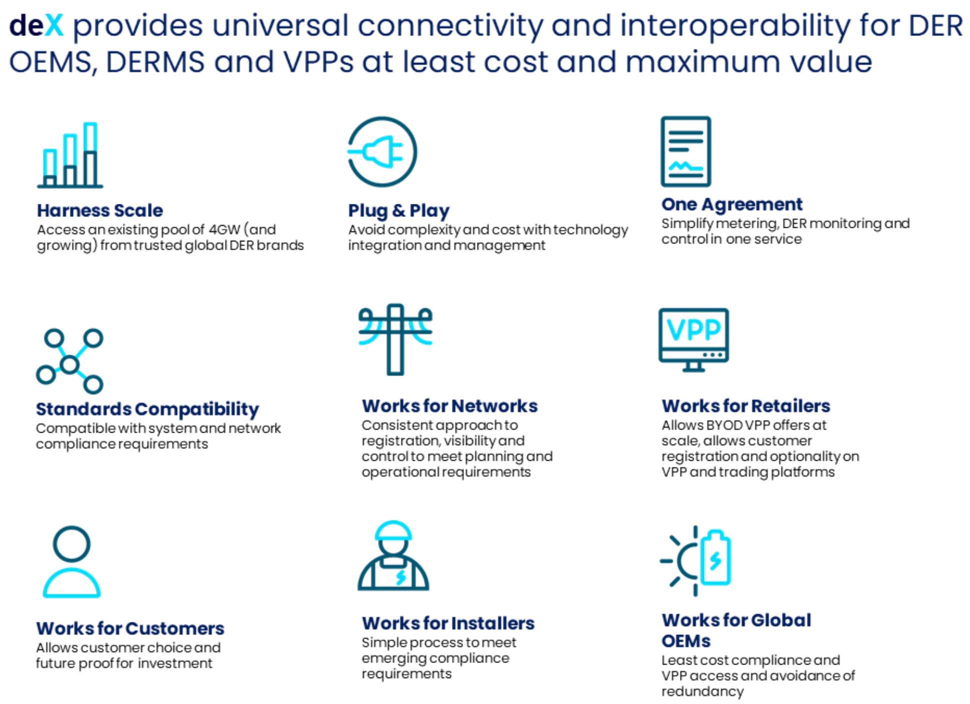

Figure 4 deX platform benefits

2.2 | Device integration and connectivity

The Intellihub Demand Flexibility Platform offers multiple ways to connect multiple device types and manufacturers to retailer VPP Platforms or network Demand Management Platforms. The two connectivity pathways are through the OEMs APIs via the cloud, and via Intellihub meters. More details on both pathways are provided below.

2.2.1 | Integration via OEM Cloud

Integrations via the OEM cloud are enabled through partnership with OEMs and the establishment of APIs that connect the Platform with the OEM's own cloud-based monitoring and control system. This cloud solution is considered low cost and scalable as it can utilise a devices' existing cloud connectivity via the consumers existing home internet connection.

The deX platform can support any future implementation of Public Key Infrastructure (PKI) with OEM cloud integration. The platform also supports multiple alternatives mechanisms to CER integration to deliver the maximum controllable DER fleet across networks and vendors.

2.2.2 | Integration via Intellihub meters

This pathway involves establishing a connection to devices through Intellihub's smart meters and its onboard communications capability to retrieve telemetry data and control devices. The communications modem linked to the smart meter contains multiple technologies for connectivity including LTE-Cat M1, Wi-Sun, and Wi-Fi. This modem is futureproofed to accommodate any future 5G rollouts.

For devices that are not able to communicate directly with the meter, a communications bridge known as the 'Intelli-Bee' can be installed to enable communications. Through this pathway, devices can connect directly to the smart meter and participate in VPPs.

PKI has been setup to support end-to-end security in this pathway, this have been set up in the manufacturing supply chain, not just for DER but for any device or meter connected into the platform.

2.3 | Device Registration

Both connectivity pathways converge to the deX platform. deX is not a VPP management platform itself and not provide any optimisation or orchestration of devices. It acts as the registration and connectivity layer that enables retailers and networks to register and control customer devices in their VPP.

VPP operators, such as electricity retailers, will integrate their own VPP management platforms with deX as a means of accessing devices. This means that VPP operators avoid the cost and complexity of integrating to multiple OEM platforms which presents a significant barrier to scaling. It also allows for an OEM and technology agnostic model that lets the consumer choose which devices they install. This is similar to 'bring your own battery' models but with a more extensive range of compatible devices and OEMs.

2.4 | Customer Acquisition

The target customers of Intellihub's flexible load platform are VPP operators such as electricity retailers, distribution networks, as well as CER aggregators. The end consumer is an indirect customer, with the retailer, network or aggregator responsible for managing the relationship with the consumer.

Operating under a business-to-business model, Intellihub is not directly responsible for developing the exact products and services that are offered to consumers. The platform provides the underlying infrastructure and capability and that allows VPP operators to come up with innovative offers and propositions for their customers.

3 | Project update

Intellihub is working closely with Project Partner GreenSync to develop the Demand Flexibility Platform, which is powered by GreenSync's deX software. Over Milestone 1 and Milestone 2 the platform has been enhanced with the following capabilities:

- Connectivity to enable control of residential electric resistance hot water systems by integrating the operation of controlled load circuits in Intellihub meters to deX.
- Development of a CSIP-AUS Utility Client that achieved CSIP-AUS listing with SAPN. Solar inverter OEMS that achieve this listing through deX can therefore be dynamically controlled in accordance with the CSIP-AUS standard.
- Onboarding of multiple industry participants as customers of the Demand Flexibility Platform, with more than 100,000 devices currently registered and available for control on the platform.

Over the remaining project milestones, Intellihub will continue to support customers of the platform with device registration and control, and will be looking to scale the platform and acquire more customers.

Additional functionality will also be developed to enhance the platform to support battery, EV and pool pump OEMS for device registration and control in a VPP.

4 | Milestone 2 Lessons Learnt

The following sections describe preliminary lessons learnt to date on the project, focusing on Intellihub and GreenSync's learnings to date working with the industry to develop and scale VPPs.

4.1 | Standards adoption is still at an early stage

The DER Integration API Technical Work Group has developed the CSIP-AUS[2] standard to facilitate easier integration with CER Devices. The continued adoption of this standard will streamline the process of integrating with OEM platforms, essential for achieving large scale registration and active management of CER devices[3].

The development of CER interoperability standards such as CSIP-AUS potentially represents a tangible improvement in the management of CER devices. However inconsistent application of these standards across OEMs has not yet resulted in uniform equipment behaviour.

As deX has been developed and integrated across multiple CER devices, challenges related to the diversity of OEM cloud platforms have emerged. This has various impacts on the overall reliability, testability, scalability and testability of the system.

A discussion on the observed impacts and its implications are provided in the following sections.

4.1.1 | Reliability

Reliability of a platform's is defined by its ability to repeatably execute its intended function adequately over a specified period of time without failure. The reliability of the end-to-end solution depends on multiple technology platforms, each contributing to the functionality required to deliver the overall solution.

For deX this means CER devices can be dispatched, modes of operation changed, and telemetry is delivered, all in a timely manner. In its role as the aggregator, deX ensures the seamless integration to all the OEM platforms to provide a standard interface to our customers, streamlining interoperability. Below are two scenarios which require support from the deX platform to resolve and provide a reliable service:

Supporting OEMs to meet CSIP-AUS compliance.

- A number of OEMs depend on the deX platform for assistance in achieving complete compliance with the CSIP-AUS standard. These OEMs have incorporated a portion of the required functionalities, relying on deX to provide the remaining capabilities necessary for their devices to comply fully with CSIP-AUS. For instance, certain OEMs lack the superseding functionality that allows a new dispatch schedule to override any existing schedule within a device. To address this

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[2] CSIP-Aus (Common Smart Inverter Protocol) is the Australian derivation / implementation of the IEEE 2030.5 standard that has been mandated for inverter-based resources in California.

[3] Common Smart Inverter Profile Australia - Australian Renewable Energy Agency (ARENA)

gap and ensure compliance, this functionality has been integrated into the deX platform on behalf of these OEMs.

Differences in OEMs implementation of CSIP-AUS standard.

- Even among OEMs that fully meet the CSIP-AUS standard, implementation of functionality varies. For instance, in the superseding functionality, we observe differences in how dispatches signal they are no longer the active schedule. To improve system reliability and service predictability, we have introduced new features into the deX platform to address these variations. These enhancements ensure a return to regular service following a superseding dispatch event. By centralising this functionality in deX, we aim to simplify operations, however, this implementation could heighten risk in situations with unstable device communications.

- As we work with OEMs to gain full CSIP-AUS compliance in March 2024, we are seeing some ambiguity with regards to the process of testing and certification. As a result, different OEMs will implement the standard and pass tests in a different manner. For example:

  1) Dynamic telemetry post rates are in some cases implemented for a given period (then reverting to the default of 5 minutes), or in other cases it will automatically revert to default after some time period.

  2) Dynamic telemetry post rates may also be implemented by up-sampling in the vendor's cloud platform, and in other cases by pushing that data from the field at the new rate.

Moving forward, we will work with the industry, OEMs, the standards committee, and certifying organisations to improve these components of the CSIP-AUS compliance process.

4.1.2 | Scalability

The scalability of a system is defined by its ability to increase or decrease performance or cost in response to changes in system processing demands. The deX platform is designed to efficiently scale both up and down in performance (in some cases without any human intervention), and optimise cost as necessary.

The platform relies on the collection of telemetry data and the active management of CER devices through time dependent control commands. Critical components in data delivery include the OEM platforms and the connection to CER devices, typically via the consumer's home internet service.

As we have scaled the platform we have identified that some OEMs platforms are not designed for the type of real time collection of telemetry data and execution of control commands that are required to operate the demand flexibility platform. We have worked with the OEMs to upgrade their systems to handle the expected increase in the number of CER devices enrolled in the platform.

In addition to this we have also seen that the home internet connections introduce variable latency and communication failure, impacting the collection of telemetry data and delivery of control commands sent to the CER devices. The platform relies on CER devices to report their status to deX. This approach mirrors the CSIP-AUS model for events, where key operational status is reported to the CSIP server. However, there will be a portion of the fleet which will be impacted by either the variable latency or communication failures leaving the status recorded in deX in an unknown state.

This is not unexpected given the nature of large distributed systems like deX, which typically operate under an eventual consistency model - it is expected that due to network delays, failures or other issues there can be periods of time when different parts of the system have difference versions of data. Customer use of statistical models for dispatch response may be necessary to mitigate some of these challenges.

4.1.3 | Maintainability

System maintainability is defined by the ease with which a system can be changed to improve performance, correct faults, or adapt to changing needs.

The end to end solution involves the interconnectivity of multiple parties, and small changes in a minor component can cause larger issues. Regular testing and verification are critical to manage the ongoing maintenance and stability of the platform.

deX's control over CER devices depends on the stability of the OEMs platforms used to integrate with those devices. Over the past twelve months multiple OEMs have made changes to their platforms which have required varying degrees of change to support them in deX. Such examples include:

- Modification of identifiers used for existing devices, resulting in a need to transition away from the old ID to a new ID.
- Addition of new functions to support CSIP-AUS requirements has meant deprecation of existing functionality; we have multiple OEMs changing the way telemetry and events are delivered through their platforms, requiring significant change to the deX platform to support.

Whilst some change and evolution is inevitable, we believe the current volume of change will slow as adoption of CSIP-AUS continues.

As more OEMs join, the complexity of managing the deX platform will increase. To reduce the level of complexity, we're investing in software verification and tools to perform functions like spotting outdated or vulnerable dependencies. These tools and processes are covered in the Australian Energy Sector Cyber Security Framework (AESCSF)[4] audit.

4.1.4 | Testability

Testability is defined by the degree to which a system or component facilitates the establishment of test criteria and the performance of tests to determine whether those criteria have been met. Testing from end to end the entire platform, built with components from multiple vendors, presents significant challenges. Distributed systems, exhibit complex behaviours at scale that are not easily or cost effectively tested. In the context of managing CER, validating the operation of the physical devices at scale remains a challenge.

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[4] Available here: https://aemo.com.au/-/media/files/initiatives/cyber-security/aescsf/2023/the-2023-aescsf-overview.pdf?la=en

The architecture of the deX platform is highly testable with regard to validating performance of individual components. We continue to extend the performance testing capability of the platform to characterise and validate performance as it scales to greater numbers of connected CER devices, including by:

- Enhancing our testing frameworks so that deX integrations, whether developed by GreenSync or others, can be verified efficiently. Our goal is to streamline these processes toward self-certification for integrations.
- Ensuring the complexity of testing and certification are kept to a minimum necessary to validate operation.

4.1.5 | Device registration remains a challenge to CER control at scale

To operate as a viable market, the existence of CER needs to be well known and understood. This leads to the obvious need for a registry of CER, capturing the market relevant information allowing for exchange.

Given the distributed nature of the CER, a clear and simple on-ramp to the registry is a critical capability for the deployment of CER control at scale. A robust end-to-end approach is required to achieve high success rates and to ensure that program objectives are met.

There are currently no common approaches for device registration in CER standards (e.g. IEEE 2030.5). To address this gap, in partnership with solar inverter OEMs that collectively make up >90% market share, GreenSync has developed an approach for registration that facilitates CER registration.

This section focuses on the challenges of registration with Solar PV CER[5].

4.1.6 | Registration process overview in deX

The completion of registration in the deX Platform comprises three key steps.

1. The submission of a registration request as a demonstration that consent has been provided by the owner to interact with the CER device. The registration request can contain additional information required for the CER to be registered in deX but not collected by the OEM e.g. NMI.
2. The response to this request confirming (or otherwise) the availability of, and providing verified details for, the CER device.
3. The creation of a resource entity in the platform, including all relevant annotations/details.

Once the resource has been registered, it is available for:

[5] Registration of hot water systems in comparison is simpler as there are fewer parties involved, the systems and processes for revenue metering are more mature, and those devices are well known through the existence of a load control tariff associated with the NMI.

- Details to be retrieved;
- Contracts for telemetry, dispatch controls and instructions to be formed;
- Dispatch controls and instructions to be sent, telemetry to be received (once contracted).

This process is illustrated in Figure 5 on the next page.

Whilst every effort is made to ensure accurate data is provided, due to the variability of OEM and installer processes it has proven very challenging to successfully register devices at first effort 100% of the time. We have developed workarounds to identify failed registrations, amend missing or invalid data, and implement retries. This is an area where further work is required, ideally to standardise the process of registration across the industry to drive portability and compatibility of this critical process.

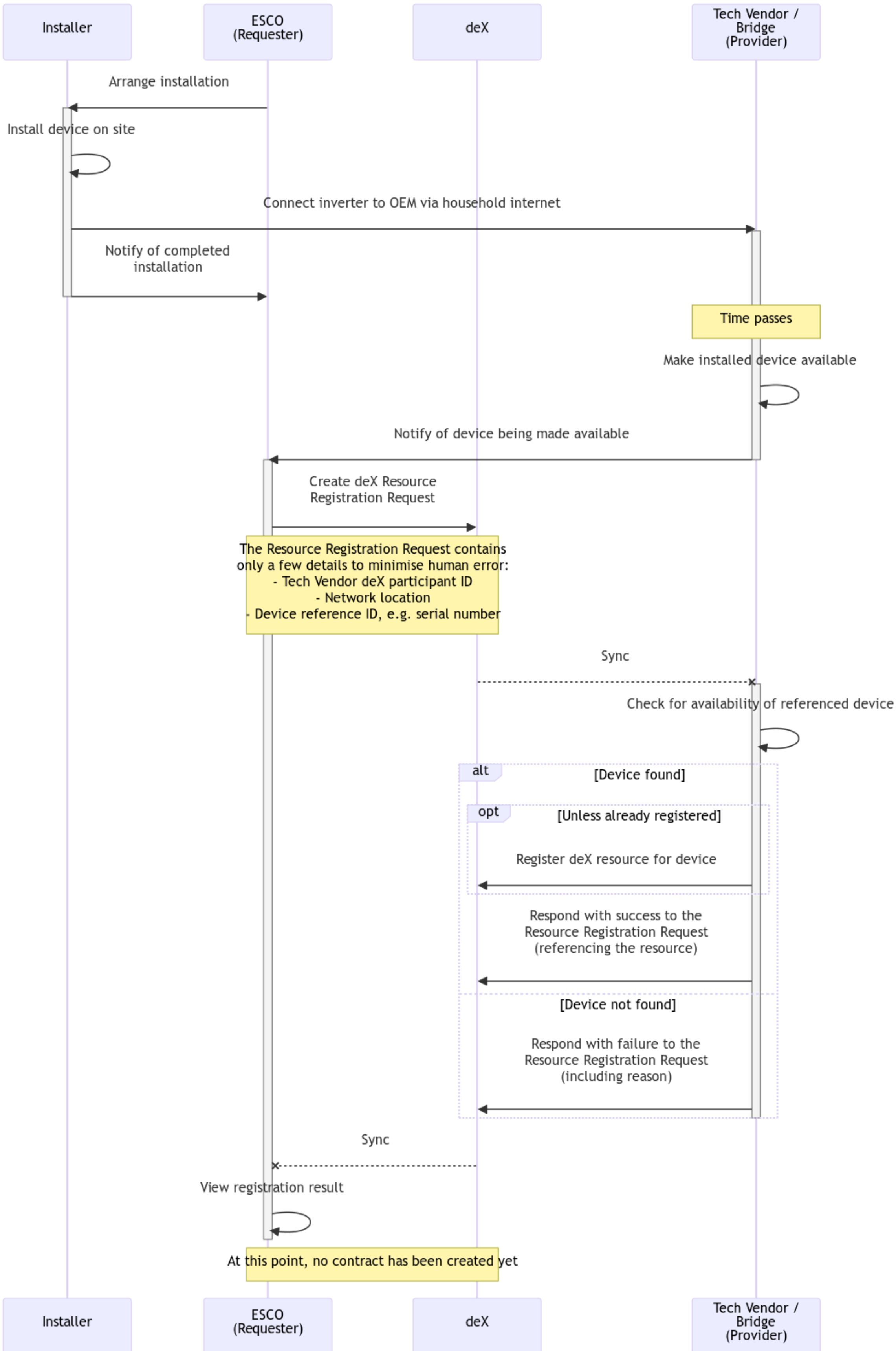

Figure 5 Registration process of devices in deX

4.1.7 | Data correctness

Through the process of CER registration, the site is first registered. The data provided during the CER registration process ties the CER (serial number or other vendor unique identifier) to a location (an NMI).

- NMI and site location
- Inverter Serial number/vendor identifier
- Participants (owner, agents, networks, retailer, etc)

This data must be correct and complete for registration to proceed successfully. The most common errors during registration involve the correctness of this data across the multiple systems involved:

- NMI is not valid in form or not correct for this site location;
- NMI does not exist in the vendor cloud platform; or
- Serial number does not exist in the vendor cloud platform.

We have seen indications that many vendors are converging on common platforms to support installation. As this trend continues, we trust this will ensure data correctness improves without increasing costs for consumers.

As registrations grow, we expect that some data analysis techniques may assist to identify root cause and remediate with minimal manual intervention.

4.1.8 | Vendor consistency

Every integration with a vendor is specific to the vendor's cloud platform. This creates a degree of inconsistency between different integrations, as the implementation behaviour varies.

This variation becomes problematic in defining robust resolution processes for registration failures. Some examples of this variation include:

- Some vendors will ensure the CER is connected to the vendor cloud at the point of registration, whilst others do not.
- Some vendors validate NMI and site information prior to registration on their own vendor cloud, others do not.

When the CER comes to be registered for control through deX, these differences create different causes of registration failure. This results in more complex processes to remediate the issue between GreenSync, vendors, and our customers.

4.2 | There is an emerging business case for retailers to curtail solar

Solar inverters are a form of flexible supply rather than flexible load, however they can still play an important role in VPPs by dynamically curtailing exports when surplus solar is creating grid stability issues or negative wholesale electricity prices. This value can potentially be passed on to consumers in the form of a financial incentive.

According to AEMO, Australia's 3.1M rooftop PV system accounted for 12.1% of the NEM's total generation in Q1 2023, contributing more the generation mix compared to utility scale solar, wind, hydro and gas[6]. This is forecasted to increase almost five-fold by 2050 – with the total capacity of these systems increasing from 19GW to 86GW[7]

Although there are emerging compliance requirements for these systems to support dynamic export limits, majority of these systems are not controllable today. Industry initiatives to curtail solar to date have been focused around network operator use-cases to manage minimum demand and alleviate local grid constraints.

There is an emerging use case for retailers to curtail solar in response to negative pricing. There has been a consistent trend of increasing negative price occurrence in Queensland, New South Wales, Victoria, and South Australia, as shown the below figure extracted from AEMO's Quarterly Energy Dynamics Q4 2023 report:

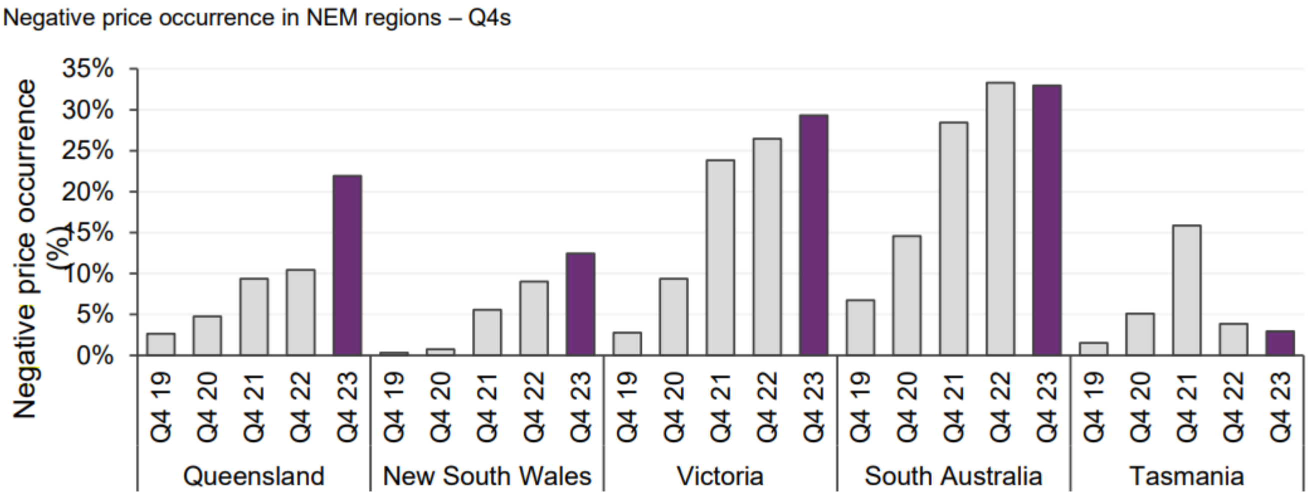

Figure 6 Increasing frequency of negative price occurrence in Q4 from 2019 to 2023 – Extract from AEMO QED Q4 2023

New South Wales and Victoria reached their highest ever negative price occurrences at 12% and 29%, with

[6] AEMO. Quarterly Energy Dynamics Report Q1, April 2023. At https://www.aemo.com.au/energy-systems/majorpublications/quarterly-energy-dynamics-qed.
[7] AEMO – Step Change scenario. Draft 2024 Integrated System Plan for the National Electricity Market, December 2023. At https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2023/draft-2024-isp-consultation/draft-2024-isp.pdf

Queensland and South Australia recording its second highest negative price occurrence at 22% and 33%. According to AEMO, negative price occurrence were concentrated during daylight hours of 10am to 2pm, this was driven by increased output of grid-scale and rooftop PV.

Retailers exposed to the energy spot market will incur a cost when their customer's rooftop PV systems are exporting to the grid during negative price periods. The following sections outline how retailers can utilise the platform to control rooftop PV inverters, and also provides an estimate of the financial benefits of solar curtailment.

4.2.1 | Solution overview

As part of this project, Intellihub is trialling a technology solution that offers retailers and networks control functionality to dynamically adjust the settings of solar inverters enrolled in their VPP. In return, they can offer their customers incentives to participate in their dynamic solar export program.

Connectivity from solar inverter OEMS to deX has been established through APIs integration to the manufacturers cloud. In the future this can also be facilitated through Intellhub's meter backhaul. Connectivity channel, retailers and networks would integrate with the deX platform to register and control these devices in their VPP, enabling control of inverters over multiple OEMs and connectivity channels. A conceptual view of the solution is shown below in Figure 9.

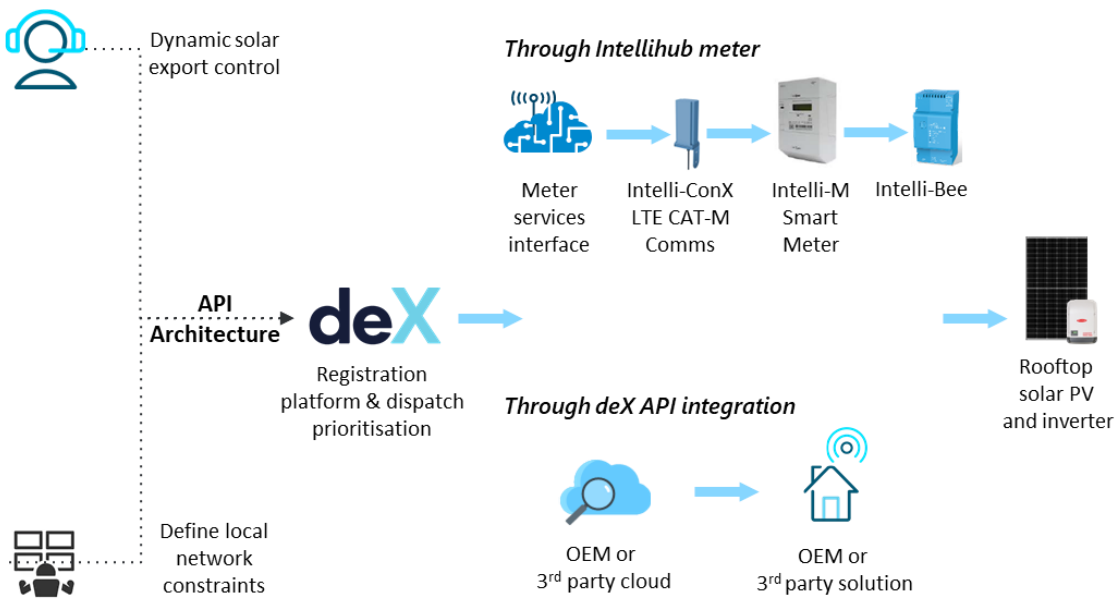

Figure 7 Control of solar inverters through Intellihub smart meters and deX

4.2.2 | Potential retailer financial benefits from solar curtailment

A key area of uncertainly for retailers is if the business case for solar curtailment to avoid negative pricing will yield meaningful financial benefits. Intellihub understands that this is a key input into retail product design for customers, where expected financial benefits of this service are directly related to the level of incentive that can be provided to customers. For example this can be provided in the form of bill credits, financial payments, or a lower retail tariff.

To assist retailers with developing their business cases, Intellihub has collaborated with Evergen to conduct a preliminary analysis on the potential financial benefits of solar curtailment.

4.2.3 | Methodology

Two kinds of solar curtailment approaches were considered based on inverter capabilities:

1. Gross curtailment or inverter curtailment where the solar inverter is turned off so the site completely stops generating solar
2. Net curtailment or grid curtailment where the power rate of the solar inverter is reduced to match the site load so that the energy requirements of the site are met but no energy is exported from the site to the grid.

Four curtailment strategies were considered, as described below:

1. Schedule - Curtailment scheduled in a time frame

We evaluated the historical average and minimum prices per hour over different seasons in each state to define time periods where prices are likely to be negative. We then calculated the impact of both gross curtailment and net curtailment across these time periods. All times are in AEST in keeping with AEMO practices.

State Curtailment Period per state:

- SA 9 am - 3 pm
- Vic 9 am - 3 pm
- NSW 10 am - 1 pm
- Tas 12 pm - 1 pm
- QLD 8 am - 2 pm

2. Zero threshold - Curtailment when market prices are below zero

This scenario looks at both gross and net curtailment whenever the settlement price is zero. In this case, feeding energy into the grid will cost money making net curtailment desirable. Retailers are subject to network tariffs so drawing energy from the grid will still cost money until the market price drops low enough to offset the network tariff.

3. Network threshold - Curtailment when market prices are below the network tariff

We set the threshold according to the network tariff of the site at midday and did calculations for both gross and net curtailment.

4. **Dynamic curtailment**

This is the optimal curtailment scenario using a combination of gross and net curtailment:

- When prices are positive there is no curtailment
- When prices drop below zero net curtailment is applied, so no energy is exported to the grid but solar generation will still supply the house
- When prices drop low enough that there is a negative cost to import energy to the site gross curtailment is applied

The above strategies were recreated by using actual telemetry from Evergen's database of customers. The selected customers are split into three categories based on their inverter capacity: below 4kW, between 4kW and 7kW and above 7kW. The net cost savings was calculated and presentedin the results section. More information on the Evergen dataset can be found in Appendix A.

4.2.4 | Results

The estimated savings under a *net curtailment* approach are significant with the zero threshold and dynamic curtailment strategy, resulting in $253 and $370 of savings in South Australia for inverters with capacity between 4 and 7kW. In Victoria, for the same two strategies and inverter category, the savings are $182 and $255 respectively.

For *gross curtailment*, the Zero threshold and Network threshold strategies yielded modest savings in South Australia, resulting in net cost savings ranging from $34 to $264 per annum. In Victoria, up to $97 net cost savings is estimated using the Zero threshold strategy on inverters with a capacity greater than 7kW.

The annual cost savings for *net curtailment* are presented below in Figure 8 and Table 2, and the annual cost savings for *gross curtailment* are presented below in Figure 9 and Table 3.

Each figure shows the results for one scenario and each colour is an inverter size category. The bars show the net cost savings for each state, separated by three value streams:

- Net cost savings from avoided exports in wholesale energy costs
- Net cost savings from additional grid imports in wholesale energy costs
- Net cost savings from additional grid imports in network tariff costs

The bars for the value streams are stacked side by side and can heighten up or down depending on the contribution of the value stream to the net cost savings. For instance, under a *gross curtailment* approach, with the Schedule strategy applied in NSW, for all inverter categories, the three value streams are losses, so the three bars stack towards negative savings. Conversely, in SA for the Zero threshold strategy, the two first value streams drive positive savings (bars heighten up), whereas the third (network tariffs) creates a loss, hence the bar heightening down. The label at the top of the third bar indicates the final net cost savings for that strategy and inverter category.

The estimated savings presented in this section represents the potential value that retailers can capture by reduce solar output solar under various curtailment strategies. These savings can potentially be passed on to consumers as a financial incentive in exchange for active management of their solar inverter.

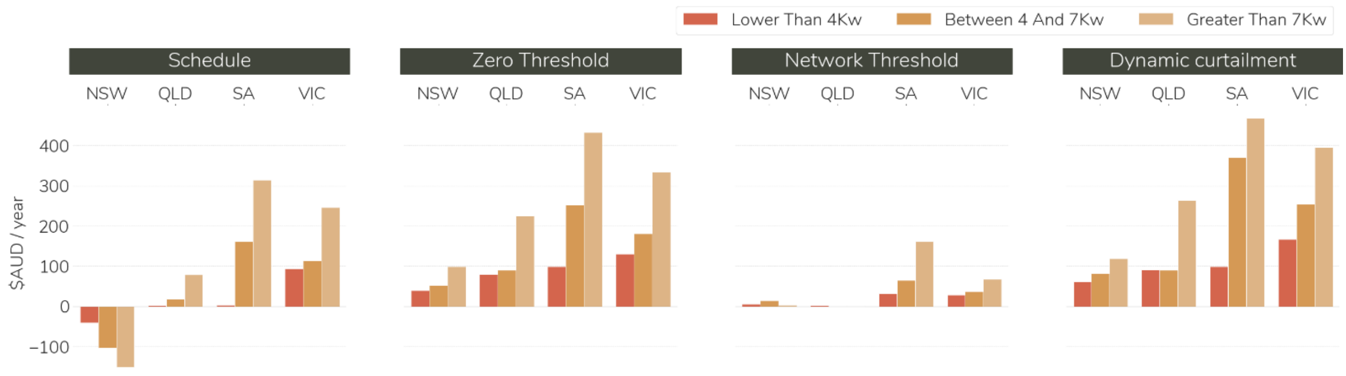

Figure 8 Net curtailment – annual cost savings

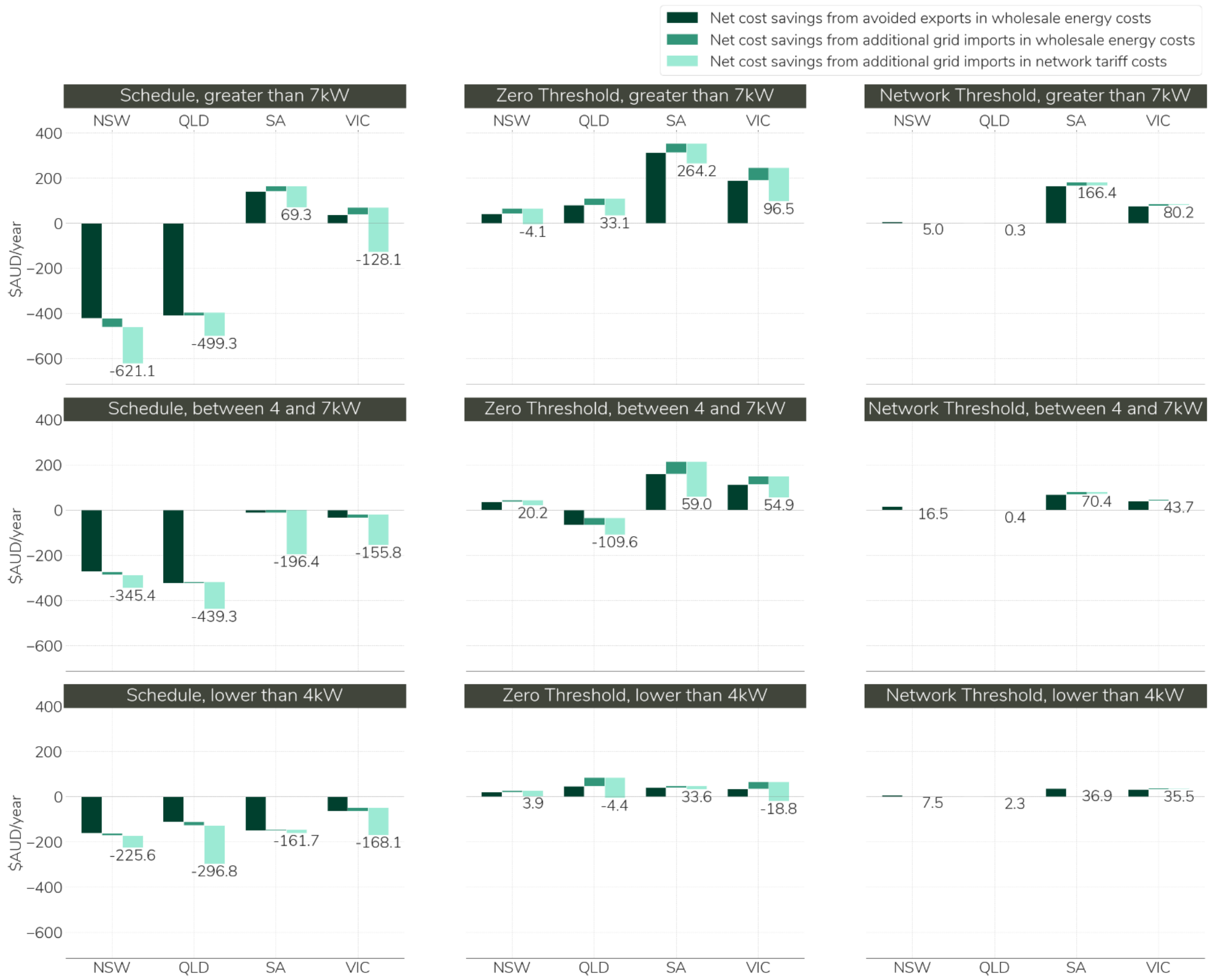

Figure 9 Gross curtailment – annual cost savings

Table 2 Net curtailment – annual cost savings

		Net curtailment												
		Inverter size	≥ 7				> 4kW and < 7kW				≤ 4kW			
		Strategy	**NSW**	**QLD**	**SA**	**VIC**	**NSW**	**QLD**	**SA**	**VIC**	**NSW**	**QLD**	**SA**	**VIC**
4	**Schedule**	- Inverter generation curtailed so there are no net exports at the site based on a daily schedule defined when hourly prices are negative	-152	78	315	247	-103	18	163	115	-40	2	4	94
5	**Zero Threshold**	- Inverter generation curtailed so there are no net exports at the site when prices are less than zero	99	225	433	335	53	90	253	182	40	80	99	131
6	**Network Threshold**	- Inverter generation curtailed so there are no net exports at the site when wholesale prices drop below the network tariff at midday	4	0	162	68	14	0	65	38	6	2	33	29
7	**Dynamic curtailment**	- Inverter generation curtailed so there are no net exports at the site when wholesale prices are less than zero, and inverter generation set to zero when wholesale prices drop below the network tariff at midday	120	265	469	395	81	90	370	255	62	91	100	168

Table 3 Gross curtailment – annual cost savings

		Gross curtailment												
		Inverter size	≥ 7				> 4kW and < 7kW				≤ 4kW			
		Strategy	**NSW**	**QLD**	**SA**	**VIC**	**NSW**	**QLD**	**SA**	**VIC**	**NSW**	**QLD**	**SA**	**VIC**
1	**Schedule**	- Inverter generation set to zero based on a daily schedule defined when hourly prices are negative	-621	-499	69	-128	-345	-439	-196	-156	-226	-297	-162	-168
		Avoided exports savings	-421	-408	140	38	-273	-323	-12	-34	-160	-111	-148	-65
		Additional grid imports wholesale market savings	-38	13	25	32	-14	5	13	16	-11	-16	4	16
		Additional grid imports network tariff savings	-162	-104	-96	-198	-58	-121	-197	-138	-55	-170	-17	-120
2	**Zero Threshold**	- Inverter generation curtailed to zero when prices are less than zero	-4	33	264	97	20	-110	59	55	4	-4	34	-19
		Avoided exports savings	41	80	313	189	36	-66	160	114	20	46	42	35
		Additional grid imports wholesale market savings	25	31	39	56	9	31	54	35	9	40	8	32
		Additional grid imports network tariff savings	-70	-77	-88	-149	-25	-75	-155	-94	-25	-91	-16	-85
3	**Network Threshold**	- Inverter generation set to zero when wholesale prices drop below the network tariff at midday	5	0	166	80	16	0	70	44	7	2	37	35
		Avoided exports savings	4	0	166	76	16	0	68	41	7	2	36	33
		Additional grid imports wholesale market savings	2	0	16	9	1	0	12	6	0	1	3	6
		Additional grid imports network tariff savings	-1	0	-15	-5	-1	0	-10	-3	0	-1	-3	-3

4.2.5 | Assumptions

- Under a net curtailment approach, solar generation needs to be matched to household load. In practice this can be difficult to manage as load can vary unexpectedly meaning extra solar energy may be exported to the grid, or there may be grid imports for short periods. In this analysis we have assumed "perfect foresight" so the curtailed solar is always exactly equal to the load.

- Settlement prices have been used rather than pre-dispatch forecasts. As forecasts are never 100% accurate there may be times when curtailment is out of sync with final prices leading to small losses.
- The additional revenue from load imports under the gross curtailment strategy is calculated by considering load that would have been covered by the curtailed solar generation when the price of the energy is negative, i.e. the settlement price plus the network tariff is below zero.

4.2.6 | Next steps and emerging challenges

Intellihub is currently working with retailers to develop solar curtailment as a retail product, and is currently supporting a major retailer with a limited trial. Intellihub will be working with retailers to prove out the technical capabilities and commercial viability of the product over the project period. Although retailers are generally interested in developing this product, there are some emerging challenges that are slowing down the scaling of the product. An overview of these challenges are summarised below:

- Challenges with enabling solar curtailment across multiple OEMs. The deX platform already has the most number of solar OEMs today, and as more OEMS are onboarded retailers can leverage the platform to offer a solar VPP product across their customer base.
- Lack of inverters with capable hardware to provide net curtailment of solar, as this requires the inverter to match the solar generation to the household load. Typically this capability is enabled by installing an additional consumption meter that communicates with the inverter. Although some states such as South Australia and Victoria have recently mandated this capability, the total volume of devices with this capability is still relatively low.
- Challenges to customer acquisition, with the retailer often not knowing the PV system characteristics and OEM of their customers' solar PV system
- Lack of understanding among consumers on the value proposition of a solar curtailment product, and what this means for their solar feed-in tariff and behind-the-meter solar consumption.
- Additional enhancements required to billing systems to compensate customers for lost-feed in tariff and any increase in energy imported from the grid under a gross curtailment approach.

Appendix A - Solar curtailment value - modelling datasets

Inverter Generation and Household Consumption Data

The telemetry data used is real data from sites on the Evergen platform over the period 1st December 2022 - 29th November 2023. Sites have been filtered for quality and completeness. We use a full year of data to capture seasonal effects and variations in market volatility.

For this initial analysis, we selected a fleet of 359 sites from the Evergen fleet. All of them are exposed to the wholesale market. We did not consider sites with network tariffs that included feed-in rates (e.g. the Ausgrid two-way tariff). The telemetry data for each site consists of power at the meter, solar generation, battery power, state of charge, and the calculated load at 5 minute intervals.

Evergen receives telemetry data from thousands of sites via our cloud integration with energy storage devices. The telemetry data includes the meter data, the battery load, and the solar generation. Therefore, we can use this data to infer household consumption.

$$Consumption = Meter - Generation - BatteryLoad$$

With the four variables above, we can create hypothetical scenarios for the household. For example, if we want to analyse the electricity bill of the household as if it didn't have a battery, we can calculate a virtual meter such as:

$$SolarOnlyMeter = Consumption - Generation$$

We use the solar-only meter explained above to conduct the solar curtailment analysis for this report. We applied three different curtailment strategies to the solar-only meter and then calculated costs based on the electricity wholesale market prices and the site's respective network tariffs.

Static site information for this analysis includes the State, DNSP, and network tariff of each site as recorded in the Evergen systems. The inverter capacity is derived from the solar generation telemetry.

Price data is sourced from AEMO — for this analysis we have used settlement prices. The network tariffs have been added to the market prices so we can calculate the cost to the retailer for each scenario.

Inverter capacity, location and average solar generation and load curves.

The following figures and tables show the distribution of inverters by size, State and DNSP, and also the average solar generation and load curves.

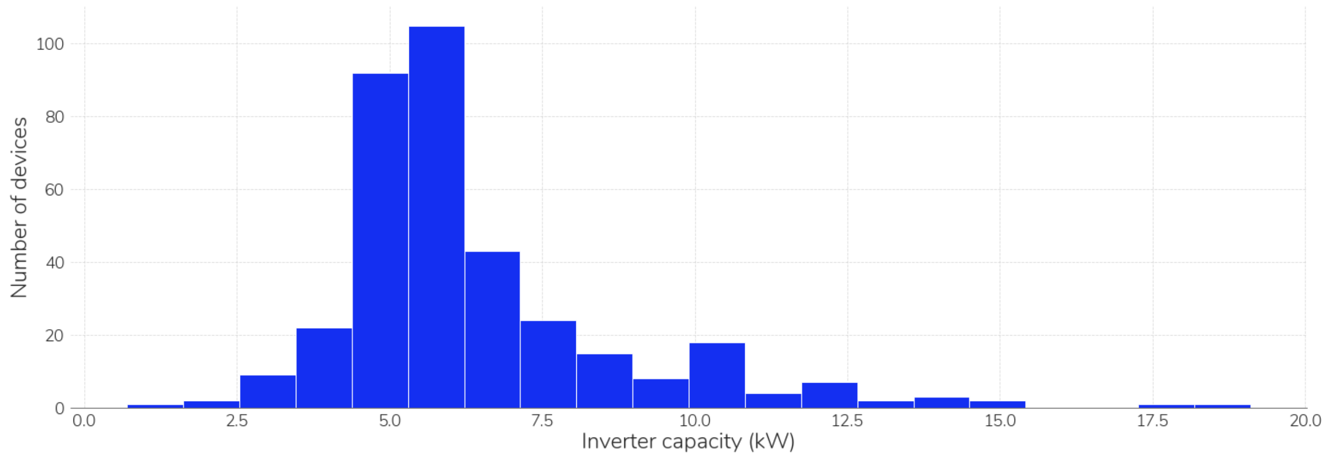

Figure 10 Inverter Sizing

Table 4 - Inverters by state and DNSP

State	Device count	DNSP	Device count
NSW	274	Ausgrid	153
		Endeavour Energy	75
		Essential Energy	17
		Evoenergy	27
		Jemena	1
		Unknown	1
QLD	29	Energex	27
		Unknown	2
SA	19	SAPN	18
		Unknown	1
VIC	37	Ausnet	16
		Jemena	2
		United Energy	9
		Unknown	10

Figure 11 - Average solar generation and load curves – by state and season

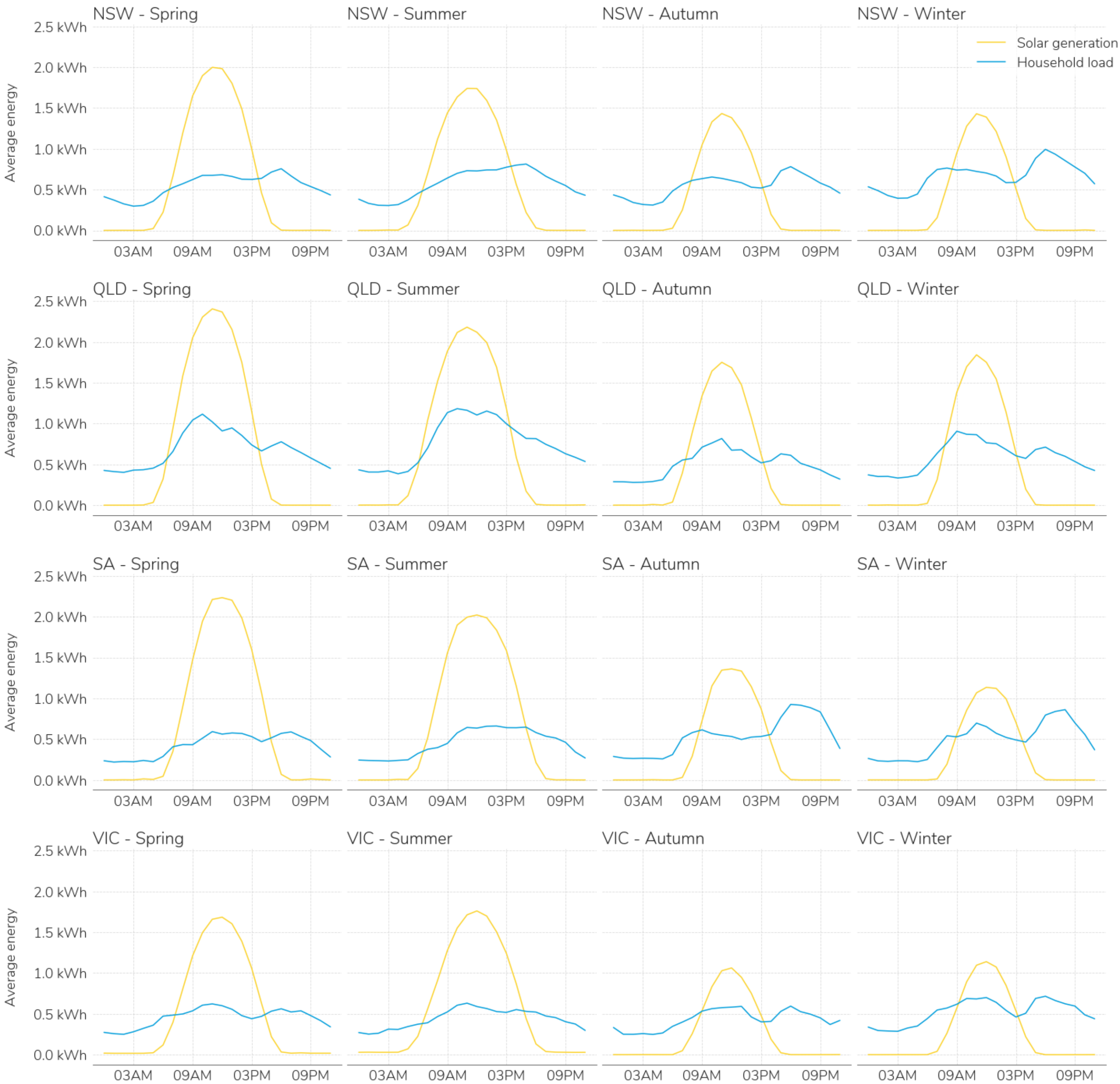

Figure 12 - Average energy prices – by state and season