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March 2022

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IEEFA.org

What Is the State of Virtual Power Plants in Australia?

From Thin Margins to a Future of VPP-tailers

Executive Summary

A Virtual Power Plant (VPP) is the aggregation of supply and/or demand response from Distributed Energy Resources (DER) such as batteries and smart appliances to participate in one or more markets.

VPPs have been lauded as a major part of the future energy mix in the Australian National Electricity Market (NEM). When the Australian Energy Market Operator (AEMO) announced its VPP demonstrations project in 2019, AEMO predicted there could be 700MW of VPPs by 2022.

This potential is some way from being realised. By the end of the AEMO VPP demonstrations in 2021, there was just 31MW enrolled, constituting a 3% market share of contingency Frequency Control and Ancillary Services (FCAS, 28MW of this in South Australia). We estimate the total household VPP fleet in the NEM is perhaps 300MW currently (Origin states it has 205MW from over 100,000 connected services, the remainder is an estimate of the sum of other aggregators).

Virtual power plants have been lauded as a major part of the future energy mix but the current margins for operators are expected to be thin.

The VPP trials discussed in this report show that aggregated DER can provide generation, demand response, contingency FCAS and, in some circumstances, network services. At present there is not large dependable revenue for customers or VPP providers, while development costs can be significant, especially for start-ups. There are major costs in the creation of software aggregation platforms, and any associated hardware to aggregate the DER, work out whether to use the capacity behind-the-meter (BTM) or which markets to export to when, and then implementing that. As a result, the current margins for VPP operators would be expected to be thin.

As a rough benchmark, the average household bill saving from VPP participation, that is unlimited aggregator access to a battery, is of the order of $200/year, far less than the savings from this battery storing BTM solar generation. The report details the range of VPP offers for customers, which vary substantially, from “no bills” guarantees to higher feed-in tariffs.

Despite the apparently thin margins on residential VPPs, there are currently about 20 commercially-available VPP products in the NEM. From our review of the

commercial VPPs, we have identified four types of residential VPP business model that have emerged so far and these are detailed in the report.

These business models are nascent and will evolve as the economics of VPPs change. As VPP fleets grow, the marginal cost of participating in any market should fall (once the sunk costs of original software platform development have been paid off) and so aggregated DER should be able to compete, especially with gas generators, to provide peaking capacity or FCAS. It is important to note that of course the establishment costs of any VPP are relatively small compared with large-scale generation and transmission. VPPs have the potential to provide fast, cheap decarbonisation, especially if governments can support electric vehicle (EV), uptake with managed charging.

A number of future revenue streams are on the horizon, including a new Fast Frequency Response FCAS service, the possibility of VPPs providing regulation FCAS, household VPPs participating in the Wholesale Demand Response mechanism, market or procurement arrangements for Minimum System Load and greater provision of distribution network services.

The greatest potential – and the reason we believe that so many retailers are moving to sell VPP products – is that larger batteries, especially in the form of EVs, will unlock much greater BTM capacity. EV batteries are currently six to ten times larger than standard household batteries and will be able to store abundant rooftop solar, making it available at any time. Stationary household batteries, often full by 11am, are greatly limited in their capacity to load shift the "solar peak". Larger batteries and larger solar systems will enable increased profits from VPPs. Energy efficiency and home energy management systems that reduce household load could further enhance the margins of VPPs.

VPP aggregator/retailer margins, currently thin, will get fatter as BTM capacity increases and if other markets open up to aggregated DER. Also, as thermal plants retire, this will create opportunities for greater VPP supply into FCAS markets. All this will increase VPP profitability and hopefully, proportionally, the value of VPP participation for households and businesses.

We would go far as to suggest that in future, retailers without VPP capabilities will struggle to be profitable. Income from sales from the grid will continue to fall. At the same time, the volume of exports from DER will increase, creating opportunities for DER aggregators able to harness this fleet for wholesale and FCAS market participation. Along the way there will be commercial opportunities in selling solar, batteries and Evs and financing these purchases.

Retailers without VPP capabilities will struggle to be profitable into the future.

The other massive, largely untapped opportunity is for commercial and industrial (C&I) VPPs, drawing on the growing fleet of rooftop solar, battery storage and

energy management systems atop and within factories, offices and warehouses. There is a difference between load profiles of a lot of C&I, which is primarily daytime load (e.g., for office buildings). However, retail businesses such as supermarkets have profiles similar to residential loads. For C&I customers, there is the added financial incentive to use demand management and batteries to reduce network demand tariffs and, if aggregated, the opportunity to participate in the wholesale demand response mechanism. In addition, there's the potential for fleet EV charging from rooftop solar at C&I sites. If a C&I solar system is large enough to charge an onsite battery during the day, it could participate in a VPP, especially to meet evening peaks, even more so in winter where demand is continuing to be high.

So far only EnelX is in this space with a 350MW C&I VPP, of which 250MW is participating in the FCAS markets, largely based upon demand response and batteries, rather than the combination of rooftop solar and batteries. EnelX, the first VPP to enter the FCAS market, today has control of 90% of aggregated C&I DR resources in FCAS. However, it is certain additional C&I VPPs will emerge, with at least two companies (New Energy Ventures and GridCognition) already established to provide modelling and advice to property developers and others about the financial viabilities of solar+storage and VPPs.

Whereas previously the largest retailers owned large generators, with profitability tied to "gentailing", we see the future of retail as requiring "VPP-tailing". Inevitably at least two-thirds of Australian households will purchase rooftop solar and either a stationary battery or an EV (or two) or both. That will mean that most of the supply to these households will be BTM and that they will have excess capacity available to sell directly and via a battery to the rest of the grid. Unless a retailer has a relationship with households that enables access to these BTM resources, they will be left with only a small proportion of households to retail to, as well as no access to DER – which in the Australian Energy Market Operator's (AEMO's) step change scenario could be three-quarters of all dispatchable capacity by 2050. We suggest that these trends and customer retention are the reasons for residential VPP offers emerging despite their limited profitability. Smart retailers, aggregators and others see the opportunities and are setting up systems and business models that will evolve and expand in future.

On 9 March, after the report was drafted, Origin announced plans to expand its 205MW VPP to 2,000MW within four years from batteries, solar, demand response and EV chargers, supporting the argument put forward here that the future of retail is tied to aggregated DER. For one of Australia's largest energy companies, the upfront capital costs of developing a VPP are "very low or even zero" in comparison with new supply from large-scale wind, solar and storage. And VPPs provide flexible supply.

Origin's presentation stated that its in-house VPP "creates lower churn, deeper engagement and seeks to fulfill customers' expectations for lower costs, decarbonisation and energy autonomy". Origin clearly understands the value of DER and that the future is in offering the combination of rooftop solar, batteries, managed EV charging and being a VPP-tailer for residential and commercial customers alike.

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Big Benefits of the Small-Scale

Introduction

Regarded as a major part of the future energy mix, virtual power plants (VPP) are a network of distributed energy resources – such as rooftop solar (RTS) and battery systems, electric vehicles (EVs) and smart appliances – working together as a single power plant, aggregated via software to participate in the electricity system.

The distributed energy resources (DER) are plugged into the grid and, with an external or embedded hardware controller and sophisticated software this supply and/or demand response can contribute to one or more markets.

Following a number of trials, commercially-available VPPs are participating in several Australian energy markets including:

- the wholesale market and, in the case of at least one commercial and industrial (C&I) VPP, the wholesale demand response mechanism
- Frequency Control and Ancillary Services (FCAS) markets
- the Reliability and Emergency Reserve Trader (RERT), and
- occasionally, providing distribution network support (also known as "grid", "non-network" or "non-wires") services, among them thermal, voltage or peak demand management.

Aggregated household DER cannot participate in the Australian National Electricity Market (NEM) wholesale demand response mechanism (WDM) for now and has participated in the RERT scheme only via trials.

In general, the highest value use of most rooftop solar and storage is in optimising behind-the-meter (BTM) consumption, co-locating generation and load while avoiding network and retail costs. However, especially as the capacity of rooftop solar systems and batteries increase and costs decrease – and, additionally, if demand can be harnessed through smart controllers – there is the potential for BTM resources to provide significant supply and demand response to meet the needs of the broader system.

Importantly, this VPP capacity is flexible so can be made available when it is needed, for example in reducing peak demand.

This report looks at the complex dynamics of DER aggregation, speculates about what the future might hold, focusing on VPPs for wholesale and FCAS market participation. A later report will examine the issues and challenges around VPPs for network support services.

VPP capacity is flexible so can be made available when it is needed.

The Fundamentals of Distributed Energy Resources

The fundamental dynamics of distributed generation, demand response and storage include:

- Generating on-site, as with rooftop solar, means co-locating generation and load. There are no transmission, distribution or retailing costs, except where additional supply is imported from or exported to the grid.
- Rooftop solar is already very cheap and is expected to halve again in price by 2024. Professor Martin Green from the University of NSW predicts module costs will drop from US$20c/kW to US$10c/kW, even with 2021 supply chain cost increases.[1] Modules are getting smaller, allowing more rooftop capacity and, in turn, lower daytime charging costs of a battery or EV.
- The business model for energy generation is changing from largely opex-based fossil fuel generation to capex-based renewables at a time of low interest rates, and there is a large amount of global capital available for investment in renewable infrastructure. With rooftop solar, there's a much higher internal rate of return (IRR)/shorter payback period than almost any other form of investment available to commercial and industrial (C&I) or residential customers. In Australia, the payback period for a household rooftop solar system is currently about four years.
- Electric vehicles are the future of transportation. With this form of distributed mobile storage, it makes sense to have charging co-located with distributed generation. It will be a lot more costly for households or fleet managers to rely primarily on off-site public or private charging stations than to charge vehicles using RTS directly.
- It's also possible that eventually battery storage and solar may both become so cheap that any inefficiencies from charging a stationary battery with RTS, then discharging it into an EV battery will be largely irrelevant.
- EVs also have huge potential to provide vehicle-to-grid services (V2G or bidirectional charging, from and into the grid). These include relieving grid congestion and providing ancillary services such as frequency and voltage management. It is worth noting that this nascent technology is expected to move quickly with vehicle original equipment manufacturer (OEM) interest and capability.

Consumer Investment in DER Is Accelerating

Australia now has more than 3 million household rooftop solar systems plus thousands of commercial and industrial (C&I) rooftop systems with a combined capacity of 17GW (out of a total PV capacity of 25GW at the end of 2021). The

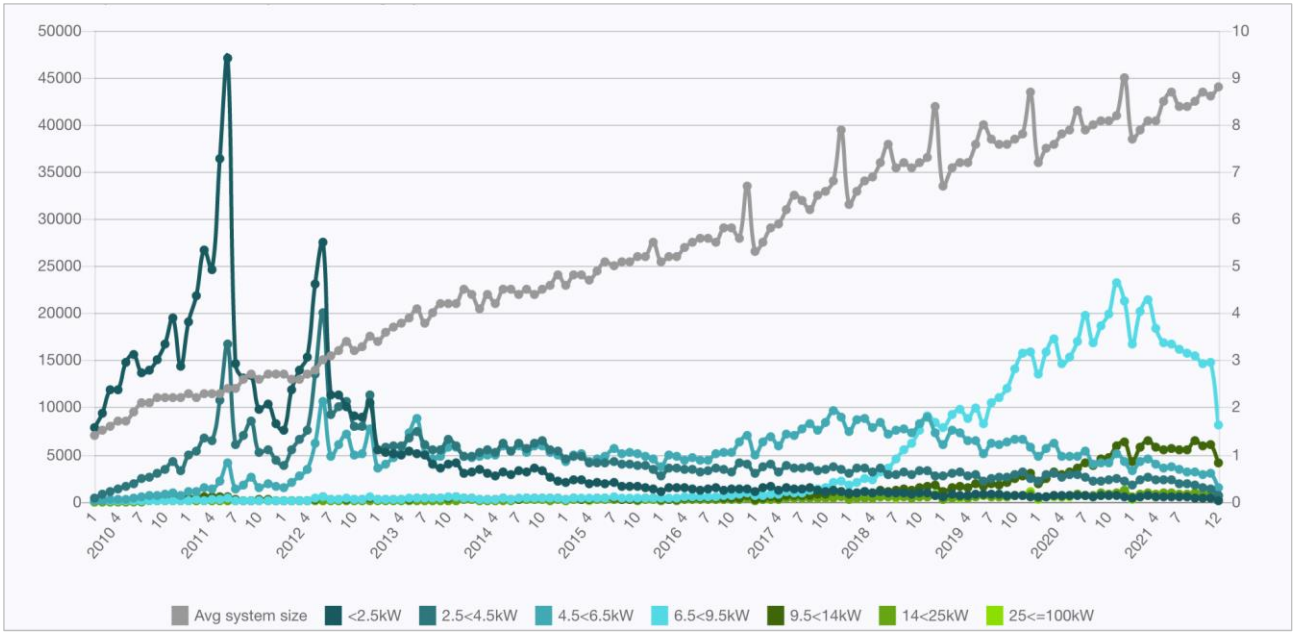
[1] Prof Martin Green. Smart Energy Virtual Conference & Exhibition 2021. 9 December 2021.

installation of 3GW successively in 2020 and 2021[2] was the world's highest per capita annual install rate.

This cumulative investment is significant. On a very rough estimate that households on average spent $5,000 each on a solar system, that is an investment of $15 billion in the past decade. As the cost of installing solar has fallen dramatically, households and businesses have installed increasingly larger systems with the average rooftop system now being 8.8kW (due to the growth in C&I 75-100kW installations, see Figure 3). Note that the most common size for a household system (40% of installations) is 6-7kW.[3] Then there are the roughly 110,000 households with battery storage and a smaller number with electric vehicles.[4]

Such investment continues to grow.

Figure 3: Australian PV Installations by Size January 2010-December 2021



Source: APVI.

Last year NSW transmission owner and operator Transgrid published an Energy Vision in which the prosumer scenario was 82GW of rooftop PV (27% of supply) and up to 80% of storage was behind-the-meter, i.e., batteries and batteries on wheels (EVs) by 2050.[5]

In December 2021, the Australian Energy Market Operator (AEMO) released its draft 2022 Integrated System Plan (ISP), the guiding document for the future of the National Electricity Market.[6] The central scenario ("step change") in the ISP forecast

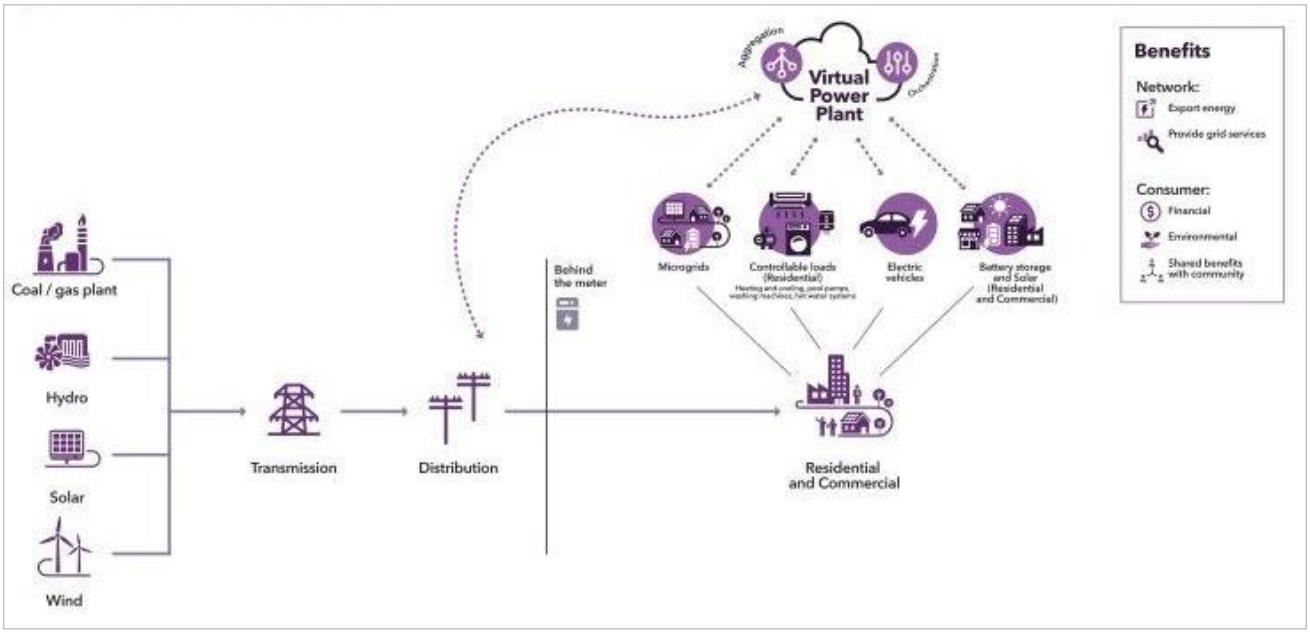
[2] RenewEconomy. New rooftop solar milestone, as Australia tops 3GW in 2021. 14 January 2021.
[3] Sunwiz. Australian Solar Year in Review "The Wrap". 2022.
[4] Sunwiz quoted in Choice. How to buy the best solar battery system. 2021.
[5] Transgrid. Energy Vision. 2021.
[6] AEMO. Draft 2022 Integrated System Plan. December 2021.

20% of consumption from DER by 2030, 24% by 2050 and, perhaps more importantly, that half of the 135GW of solar expected by 2050 would be on rooftops (a five-fold increase in the current distributed PV) and three-quarters of all dispatchable capacity would be distributed by 2050.

How Does a Virtual Power Plant Work?

Figure 4 shows how microgrids, controllable loads (aka smart appliances, such as air conditioners), EVs and battery storage and solar can all be included in a VPP.

Figure 4: Diagram of VPP Operation



Source: AEMO.

VPPs are coordinated in two ways. Some use a cloud-based gateway – where the inverter (or other DER) has embedded energy management capability, such as in sonnen and Tesla inverters. Others use an on-site gateway – a dedicated device that manages DER BTM, such as the Reposit smart controller or SwitchDin's droplet. The on-site gateways generally have the advantage of being able to manage multiple devices BTM and so optimise consumption, storage and exports in line with price signals, but some inverters (such as SolarEdge's Energy Hub inverters) also include these capabilities.[7]

By aggregation, we mean a third party (an aggregator or retailer) contracts with consumers for access to their DER. This is usually in the form of an agreement for access either under certain conditions (such as high wholesale prices), for a maximum number of times per year or for unrestricted access. In return, DER

[7] Enea consulting. Smarter homes for distributed energy. February 2022.

owners receive financial rewards that vary greatly in their form. Current residential VPP offers include:

- Upfront hardware (battery or other technology) discounts
- No retail bills guarantees
- Fixed financial (or other) rewards, and
- Variable financial (or other) rewards.[8]

What Can We Learn From the VPP Trials to Date?

There have been several trials of Virtual Power Plants (almost all with funding from ARENA, the Australian Renewable Energy Agency) in the National Electricity Market (NEM) in the past five years. All projects have been focused on rooftop solar plus battery storage with no contribution to date from household demand response or EVs. This section looks at what we can observe from the published reports on their successes and challenges, especially in terms of the financial viability of VPPs.[9]

AGL VPP Project

AGL announced the first large-scale wholesale market-focused VPP project in late 2016 with ARENA funding.[10] It included the sale and installation of 1,000 BTM battery energy storage systems (BESS) in metropolitan Adelaide to create a total 5MW fleet. This fleet participated in the AEMO demonstrations for wholesale market and contingency FCAS provision (see below) using the Enbala cloud-based control and optimisation platform.[11]

Simply Energy VPP Project

This ARENA-funded project resulted in 1,361 household BESS delivering 6MW of flexible capacity (wholesale and FCAS) to the South Australian (SA) electricity grid.[12] Tesla batteries were offered to solar households at three levels of subsidy (funded by the SA Government) and under several different commercial offers over the life of the project.

Starting in March 2018, the project included platform provider GreenSync (it's not clear what GreenSync delivered), SA Power Networks (SAPN) and SwitchDin's energy management software. Simply Energy (a retail branch of French company Engie) collected all the wholesale arbitrage, which was $115/year per Tesla Powerwall between Jan 2019 to June 2021. Simply Energy reported sales of 809 Powerwalls over this time, suggesting a total of $93,000 in wholesale savings for

[8] Enea consulting. Smarter homes for distributed energy. February 2022.
[9] For greater detail on technical learnings from the trials, we recommend reading the project reports. The focus of this report is the financial status and future of VPPs.
[10] AGL Energy. Virtual Power Plan in South Australia. Final Milestone Report. October 2020.
[11] Enbala. AGL Chooses Enbala for Virtual Power Plant Project, 10 December 2018.
[12] Simply Energy. Simply Energy VPPx – Stage 3 Knowledge Sharing Report. August 2021.

Simply Energy.

The project was also part of the VPP AEMO demonstrations (discussed below), earning $482,000 in FCAS revenue between 20 October 2020 and June 2021. This FCAS revenue collected by Simply Energy was at an estimated cost of $25.31 per customer per year in battery use.[13] It is important to note that the project only achieved 61% "dispatch effectiveness" (only 61% of the fleet met the requested dispatch signal) due to technical constraints including export limitations, excessive grid voltage and to a lesser extent, communication issues.

In terms of financial benefit, customers' electricity bills reduced on average by $668/year because of electricity provided by the battery rather than grid imports. Customers did not receive any benefit from wholesale arbitrage or FCAS. Simply Energy received the full revenue from these services.

AEMO's Virtual Power Plant Demonstrations

The Australian Energy Market Operator (AEMO) established VPP demonstrations (again with part-ARENA funding) in 2019 to:

- Allow VPPs to demonstrate their capability to deliver multiple value streams across FCAS, energy and potential network support services.
- Provide AEMO with operational visibility to help AEMO consider how to integrate VPPs effectively into the NEM.
- Assess current regulatory arrangements affecting participation of VPPs in energy and FCAS markets and inform new or amended arrangements where appropriate.
- Provide insights on how to improve consumers' experience of VPPs in future.
- Understand what cyber security measures VPPs currently implement, and whether their cyber security capabilities should be augmented in future.[14]

In the NEM there are six contingency FCAS markets: to raise and lower frequency on a fast (six-second), slow (60-second) or delayed (five-minute) basis. Locally enabled market participants respond to frequency changes without a central command or instruction. The trials allowed DER portfolios to participate in contingency FCAS for all six services (see Table 1 and Figure 5).

The trials began in July 2019 and in September 2019 gained their first participant with Energy Locals in a consortium with Tesla. The trials ended in 2021 with eight participants (see table 1) with a total registered capacity of 31MW (27MW of which was in South Australia, where the state government gave generous battery

[13] Note total cost is impossible to calculate as it is unclear if all batteries were in place by 20 October 2020.
[14] AEMO. Virtual Power Plant Demonstrations. 2019.

subsidies). Energy Locals/Tesla had more than half (16MW) of this and AGL had about 20% (6MW). Simply Energy's 4MW was the only other significant VPP, the remainders were small and late to engage. To give a further sense of scale, the 31MW constitutes a mere 3% market share of contingency FCAS.

Participation was open to any technology, though all VPPs were based only on household batteries connected with solar systems. Approximately 7,150 consumers were involved, or almost 25% of residential customers with registered batteries in the NEM (and about 6% of the estimated 110,000 BTM batteries in the NEM).[15]

Table 1: AEMO VPP Demonstrations Participants

	Energy Locals (Tesla SA VPP)	AGL	Simply Energy	sonnen	ShineHub	Energy Locals (Members Energy)	Hydro Tasmania
DUID	VSSEL1V1	VSSAE1V1	VSSSE1V1	VSNSN1V1	VSSSH1S1	VSVEL2S1, VSNEL2S1	VSQHT1V1
Jurisdiction	SA	SA	SA	NSW	SA	VIC and NSW	QLD
Registration *	MC	MC	MC	MASP	MASP	MC	MASP
Battery technology	Tesla PowerWalls	Tesla PowerWalls	Tesla PowerWalls	sonnen	AlphaESS	Alpha ESS Saj/Everready	Tesla PowerPack
FCAS delivery	Proportional	Proportional	Proportional	Proportional	Switched	Switched	Proportional
Registered capacity (Aug 2021)	16 MW All cont FCAS	6 MW All cont. FCAS	4 MW All cont FCAS	1 MW All cont FCAS	1 MW All 6 cont FCAS	1 MW (x2) All 6 cont FCAS, except L6	1 MW All 6 cont FCAS

*Registration types are MC = Market Customer, MASP = Market Ancillary Services Provider

Source: AEMO.

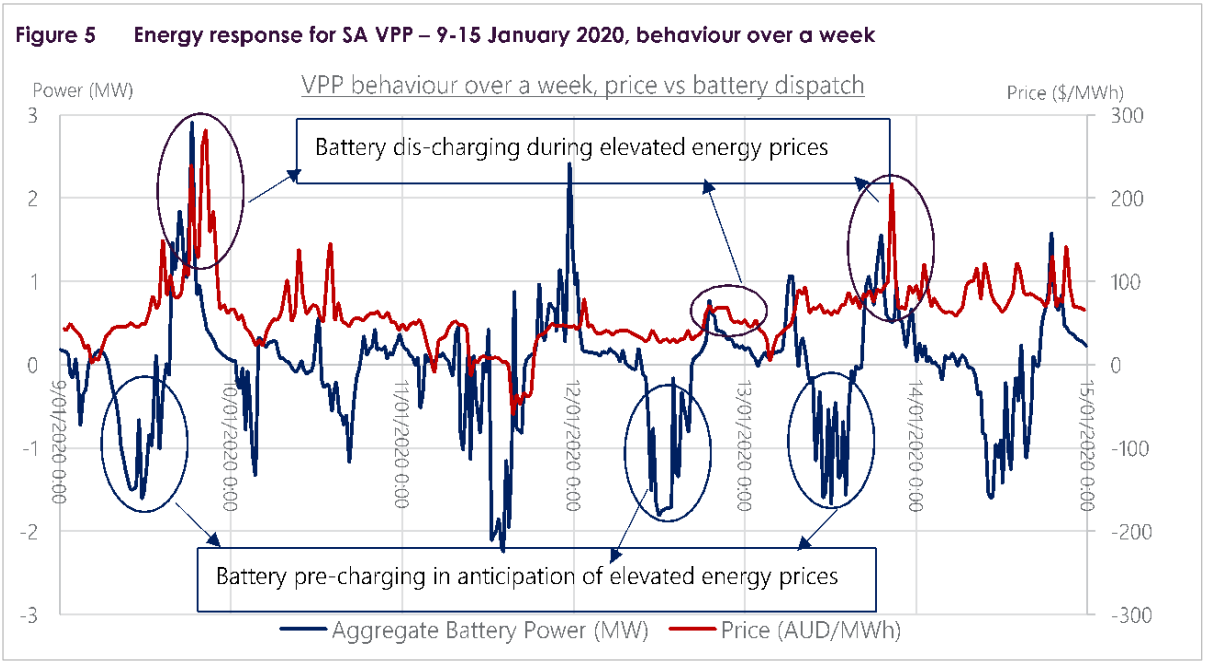
The trials found that the coordinated batteries could deliver more than one service, at times simultaneously. However, there was a potential conflict when wholesale prices were high (which incentivised battery discharge) and there was a call for frequency lower services (provided with a charging battery). In this circumstance, priority was given to FCAS services and the stabilisation of the system, regardless of the subsequent loss in wholesale market revenue for the aggregators. AEMO is now looking at exploring how dynamic operating envelopes might be used to assist, for example, by providing a contingency event envelope that can be activated as required to constrain or allow more DER exports as appropriate.

Unsurprisingly, looking at the revenue dynamics of the demonstrations, AEMO found that:

[15] AEMO. NEM Virtual Power Plant Demonstrations. Knowledge Sharing Report 4. September 2021.

VPPs are highly capable of responding to energy market prices in real time, and do so at times, however their behaviour is largely dominated by serving the household first and maximising the self-consumption of rooftop PV.[16]

Figure 5: VPP Demonstrations Example of Wholesale Market Response



Source: AEMO.

Given the DER dynamics outlined at the beginning of this report, aggregators make the decision that the highest and best use of DER is behind-the-meter. The operators of the VPPs did not metaphorically "get out of bed" for short/small price rises in the wholesale market of less than $300/MWh (see Figure 5 for an example of charging and discharging to meet elevated wholesale prices) and, even with prices above this, the response was limited. In AEMO's words, these conservative bidding strategies played out as follows:

- *Extreme high price – only three out of seven VPPs responded at times, and even so, the most reactive VPP only responded to high prices around 39% of the time. With limited storage capacity, the VPP was not able to capture longer duration price spikes without recharging.*

- *Extreme negative price – VPPs charging at extremely negative prices was observed in some instances, noting that negative prices often coincide with the typical charging cycle (middle of the day). In addition, response during negative price periods out of the charging cycle was limited. Follow-up interviews revealed that participants are less likely to charge at low prices due*

[16] AEMO. NEM Virtual Power Plant Demonstrations. Knowledge Sharing Report 4. September 2021.

to customer contracts in place.[17]

It is not clear from any of the AEMO VPP demonstrations how much wholesale market revenue was made by participants.

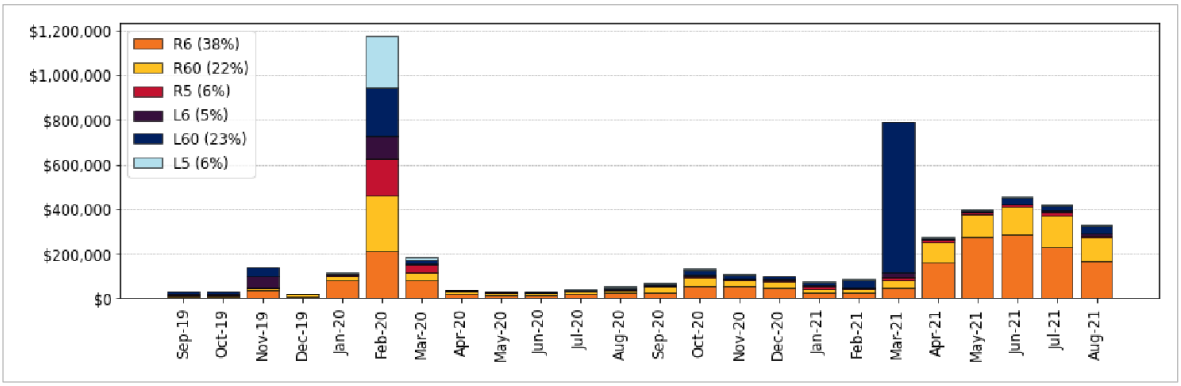
As South Australia is currently only connected to one other state in the National Electricity Market (NEM) – Victoria – it has a particular need for contingency FCAS during disturbances or separation events where SA is islanded from the rest of the NEM. Major events during the demonstrations that required contingency FCAS were:

- 16 November 2019: Victoria and South Australia regional separation.
- 13 January-17 February 2020: SA separation event.
- 12-17 March 2021: Significant price volatility in the South Australian lower 60-second FCAS market due to planned and unplanned outages on transmission lines and a power station transformer issue.

From April 2021 there were elevated FCAS prices in South Australia and increased VPP capacity (see Figure 6).

In summary, VPP revenue was largely dependent on events – two events provided 49% of FCAS revenue during the demonstrations.

Figure 6: VPP FCAS Monthly Revenue by Market (Sept 2019 to July 2021)



Source: AEMO.

Table 2 shows the revenue earned by participants over the course of the VPP Demonstrations. Clearly only Energy Locals/Tesla with the largest VPP made substantial revenue from participating in the FCAS markets.

[17] AEMO. NEM Virtual Power Plant Demonstrations. Knowledge Sharing Report 4. September 2021.

Table 2: VPP FCAS Revenues by Retailer/Aggregator

VPP Retailer/Aggregator (Capacity at End of Demonstrations)	FCAS Market Revenue September 2019 – January 2021
Energy Locals (16MW)	$2,200,000
AGL (6MW)	$99,000
Simply Energy (4MW)	$85,000
Sonnen (1MW)	$2,000
Shine Hub (1MW)	$180
Energy Locals (Solar SG/Members Energy) (1MW x2)	$0
Hydro Tasmania (1MW)	$0

Source: AEMO VPP Knowledge Sharing Report #3.

The stated cost of the demonstrations was $7.03m (which included $3.46m of ARENA funding), but this does not include the separate funding for the AGL and Simply VPPs nor the SA Government battery subsidies. It is noteworthy that the $7m was far greater than the combined FCAS revenue of all participants.

The trials, as expected, came at high cost relative to the revenue. As trials, the VPPs lacked economies of scale. There were costs involved in developing Application Programming Interfaces (APIs) to communicate with DERs and AEMO, acquiring customers and developing a VPP operating platform (VPP management software). With these costs having been sunk almost all the participants (Energy Locals, Simply, AGL, sonnen[18]) are moving to establish commercial VPP arrangements.

AEMO is looking to simplify what were regarded as complex requirements for registration and onboarding into its systems. A recent rule change determination makes a new two-way category of Integrated Resource Participant (IRP) available to aggregators from April 2023 and this should simplify the registration process for batteries.[19]

In terms of consumer benefit, the financial rewards were so variable it's hard to draw out any conclusions. Table 3 summarises the information available from AEMO.

[18] Solar Quotes. Virtual Power Plant (VPP) Comparison Table. 21 December 2021.
[19] AEMC. Integrating energy storage systems into the NEM. 2 December 2021.

Table 3: Range of Consumer VPP Demonstrations Value

Rewards:	Orchestration of the battery:
• Rewards ranging from $280-$2,550 p.a. • Discounts on battery supply (capital expenditure) ranging from 11%-51% • Exclusive retail agreements ranging from 32% below to 16% above default offers • Non-financial benefits (promoting renewable energy, community benefits and grid support)	• How many times could the battery be managed under the VPP per annum? **30 – unlimited, unlimited most common** • How much of the battery capacity was reserved for household use? **0 – 30%, 20% most common**

Source: AEMO.

Technical Issues: Visibility, Forecasting, Dispatchability

From AEMO's perspective, the VPP demonstrations revealed several ongoing technical issues with DER fleets.

The first is the lack of visibility of the size of the fleets and when they might come online. There was some under-delivery due to changes to settings in firmware and, as discussed above, inconsistent responses to energy prices. There were, at times, communication drop-outs with 30% of fleet (resulting in 5-8% of data missing), largely due to the use of household internet delivered over wi-fi.

As a result, forecasting errors were 9% on average for one-hour ahead forecasts and 25% for day-ahead forecasts around the time of record minimum demand for South Australia (14 March 2021 – for total load capacity at the time of 10.92MW). The 12-hour ahead forecast errors were the highest at 42%, equating to ~4.6 MW

AEMO is concerned that with more VPPs, the market will become more volatile, with reduced forecasting ability and increased ramping and swings.[20]

AEMO has proposed the following to address its operational needs:

1. **Visibility.** Submission of near real-time operational VPP data to AEMO (as was done in the VPP demonstrations). This is likely to be done voluntarily at first under the Energy Security Board's "scheduled lite" proposal.[21]

2. **Forecastability.** Increasing the sophistication of AEMO operational forecasting capabilities to accurately predict VPPs' operational behaviour.

3. **Dispatchability**. In the longer term (five years or more), having VPPs participate in central dispatch as a form of scheduled resource. This is also going to be explored in Project EDGE (see below).

[20] AEMO. NEM Virtual Power Plant Demonstrations. Knowledge Sharing Report 4. September 2021.
[21] Energy Security Board. Integration of distributed energy resources (DER) and flexible demand. December 2021.

Consumer Dimensions of the VPP Demonstrations

From reading the AEMO Knowledge Sharing Reports, it seems consumers were "mostly satisfied"' with their involvement in the VPP demonstrations but consumers and providers alike found it a complex process. For VPP providers, that translated into a resource intensive process.

AEMO's conclusion was that "future demonstrations and market design initiatives must prioritise creating a simple user experience for participants to enhance satisfaction, engagement and successful implementation".[22]

Unsurprisingly, consumers were most satisfied when their bills were lower, and they paid off their batteries faster.

AEMO also found there were regulatory gaps in terms of customer information and switching: "Careful consideration will be needed regarding the information provided to consumers who plan to participate in a VPP, and also about whether the current retail electricity process of 'explicit informed consent' will be required to switch between VPP providers."[23]

Projects Symphony and Edge

AEMO is following up the VPP trials with Projects Symphony[24] and Edge,[25] each aiming to create DER marketplaces with dynamic operating envelopes and to set up standards for efficient data flows between participants, particularly with AEMO. There is a large emphasis on creating a digital infrastructure whereby each DER will have a digital identity. This will give AEMO behind-the-meter information it has never had previously, other than in a static DER register.

Both projects plan to create "scalable and competitive trade of local network services" but their small scale may limit the possibilities. Project Edge has a total project cost of $28.03m ($12.92m from ARENA) for 1000 households, so a raw cost of $28,030 per customer. Project Symphony is even more expensive: $35m for 500 households, averaging $70,000 per household.[26]

There are no results yet from either trial, so it is unclear why the costs are so high. Project Edge includes "comprehensive cost benefit analysis to provide an evidence base for future regulatory decision making."[27]

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[22] AEMO. NEM Virtual Power Plant Demonstrations. Knowledge Sharing Report 4. September 2021.
[23] AEMO. NEM Virtual Power Plant Demonstrations. Knowledge Sharing Report 4. September 2021.
[24] AEMO. Project Symphony. 2021.
[25] AEMO. Project Edge. 2021.
[26] RenewEconomy. Western Australia to splash $35m on virtual power plant pilot. 3 February 2021.
[27] AEMO. Project Edge. 2021.

Rheem Hot Water System VPP Project

The South Australian Government, ARENA and Rheem are funding a $8.8 million project to develop a VPP using 2,400 South Australian residential hot water systems.[28] This VPP will do demand response and load shifting (for network benefits), electricity price arbitrage and, potentially, provide FCAS services. This trial commenced in 2021 and there are no results yet.

Commercially-Available VPPs and Related Market Developments

As mentioned above, only one participant (Energy Locals with Tesla) made substantial revenue from the AEMO VPP demonstrations. Despite this, almost all participants (Energy Locals, AGL, sonnen, ShineHub, Simply Energy) are continuing to offer VPP products to residential customers.

Simply Energy has expanded to NSW and Victoria and also extended its technology mix from Tesla to include batteries and solar inverters from AlphaESS, Eguana, SolarEdge, SolaX, sonnen and Varta.

New providers Energy Australia, Origin, PowerClub (with sonnen only), Discover Energy, nectr and Plico (in WA, yet to be launched) are offering commercial VPP products to residential customers.[29]

In addition, the Victorian Government has a VPP pilot program with a higher solar battery rebate ($4,174 compared with $3,500 for a battery alone) for eligible Victorians who join one of six approved VPP programs from five providers (Tesla, Mondo with Project EDGE, Reposit, sonnen and Arcstream with Q.cells).[30] The program is capped at 2,000 rebates.

The following section details the noteworthy range and innovation of commercially-available VPPs.

sonnenFlat and sonnenConnect – A Battery with Two VPP Options

Battery manufacturer sonnen (owned by Shell) offers sonnen battery customers (minimum size 4kWh) with solar a deal for static electricity fee per month ($49-69 depending on size) in return for their battery participating in sonnen's VPP via a partnership with retailer Energy Locals. Network charges are included in the sonnenFlat monthly rate and excess usage charges apply for usage above the annual allowance – sonnen's access to the battery is unlimited and "sonnen may operate the sonnenBatterie remotely at its sole discretion."

For the sonnenConnect product, customers can be with any retailer. sonnen provides a $100 sign-up reward and between 82c and $24/month to be able to

[28] ARENA. Storing excess solar from the grid using hot water systems. 6 February 2021.
[29] Solar Quotes. Virtual Power Plant (VPP) Comparison Table. Last Updated: 29 Dec 2021.
[30] Solar Victoria. Approved Virtual Power Plant (VPP) programs. 9 March 2022.

remotely operate the battery at any time for its VPP. The terms and conditions state "this capability may, from time to time, enable us to offer separate services to third parties, including but not limited to AEMO, your Distributor and/or your Electricity Retailer (as applicable), from whom we may receive payment."

Discover Energy VPP – Solar Distributor Offshoot

Discover Energy, a new start-up electricity retailer, has a VPP product for a Discover-recommended battery and inverter combination (from nearly three-quarters of the available battery and inverter brands). Discover Energy uses wholesale market arbitrage to offer customers higher effective "feed-in" tariffs than other retailers. For all NEM states other than Victoria, the rates are: first 300kWh/quarter, 45c/kWh; next 300kWh/quarter, 25c/kWh, then 9c/kWh for all after that. There is 50-50 profit sharing on trades managed by Discover Energy.

Discover Energy has full access to the battery and may discharge to about 80-90% of capacity. Discover Energy has recently registered to provide contingency FCAS in SA, NSW, Queensland and Victoria.

Discover Energy also has a partnership with ACE-EV, which plans to test early-stage vehicle to grid (V2G) capability. ACE-EV and Discover Energy aim to launch this collaboration, with vehicle testing in South Australia, in mid- to late-2022.

Discover Energy is an off-shoot of One Stop Warehouse, Australia's largest solar distributor and solar and battery installer. Installer partners who refer customers to Discover Energy get access to hardware discounts on battery and inverter packages.

Reposit – 'No Bills' VPP

Working with various retailers, Reposit currently controls more than 20MW/34MWh of distributed batteries in the NEM and participates in all contingency FCAS markets.

Reposit has a specific "no bill"' for five years guarantee, available only to households that currently have bills of less than $3,500/year and purchase a Resposit-controlled solar and battery system.

Reposit has been targeting the potential for DER to provide network services, which we'll detail in a future paper.

AGL Solar Grid Saver – Paid Household Solar Curtailment in South Australia

Alongside VPP participation,[31] AGL now has a "Solar Grid Saver" product in South Australia. This is paid solar curtailment – up to $150/year in bill credits, depending on the size of the solar set-up, for pausing household solar exports for up to 140 hours per year. This would serve to mitigate the risk of negative price liabilities for AGL, as the largest retailer in South Australia, while also reducing ramping challenges for AGL as the owner of the Torrens Island and Barker Inlet large gas

[31] AGL. Power your community with our Virtual Power Plant. 2022.

generators. This is a unique product for unique circumstances, which other retailers may look to adapt to hedge negative prices.

Origin Loop and Spike – The Biggest Household VPP Includes Demand Response

Sole among the big three gentailers, Origin has been selling solar systems to household customers for many years. Origin is currently offering a $3500 discount on a LG Chem RESU battery and a $20 credit on household electricity bills each month for five years. In Origin's "Loop" VPP, it will access the battery, capped at 200kWh discharge per year, and states it will ensure the monthly credit households receive will outweigh charge and discharge costs.[32] VPP customers also receive feed-in tariffs from their solar, but must keep their retail electricity supply contract with Origin for the five-year duration.

Origin has partnered with Californian company Ohm Connect to offer a "gamified" demand response product. This uses a gaming approach to encouraging households to voluntarily reduce their energy use at peak times, with rewards and status similar to frequent flyer programs. Origin "Spike" customers who reduce their energy use by an average of 60% compared to their baseline energy forecast of at least 1.2kWh, and who do so for more than 20 consecutive Spike Hours, can earn $250 or more per year in rewards. Origin claims to have more than 30,000 customers participating in this program.[33]

The consumer benefit from participating in this program is hard to evaluate. What is interesting is that Origin sees voluntary demand response as a cost-effective way to manage its wholesale market risk. This is indicative of the potential value of demand-responsive DER BTM.

Origin says it now has more than 205MW of assets connected in its VPP.[34] This includes demand-side resources and is several times larger than any other household VPP fleet.

It's also noteworthy that Origin's VPP offer is more generous and longer-term than those of the other big gentailers. EnergyAustralia has a three-year VPP offer with $200 on joining and $20 per grid event (up to 20 events per year), but no battery discount. AGL has a 12-month offer of $1,000 off a battery, $100 credit on joining and $45 credit per quarter for battery access.

Brighte – Technology Finance as an Entry Into a DER-based Retailer

Fintech (tech finance start up) Brighte provides fixed cost loans for solar and battery systems and other "green home" upgrades (from electric stoves to EV charging to decking) on a "buy now, pay later" model. Brighte works with more than

[32] Origin. Virtual Power Plant Contract Terms. September 2021.
[33] Origin website Artificial Intelligence and the tech behind the VPP 12 May 2021.
[34] Origin. 2022 Investor Briefing. 9 March 2022.

2,500 vendors and has provided loans to 100,000-plus households.[35]

In June 2021, Brighte was awarded a retail licence and it has flagged it will be going to market with a retail energy offering for BTM assets. Essentially this will be a DER-based retailer and aggregator using a VPP fleet as the basis for consumer benefit as well as managing risk.

Brighte is also the finance and administration provider for the first phase of the ACT Government's $150 million Sustainable Household Scheme for the purchase of household energy efficiency upgrades, which includes new and second-hand EVs.

EnergyAustralia's "On" Product – Rent to Buy Solar + Battery Over Seven Years

EnergyAustralia has a vanilla VPP offer and a new novated lease-style solar and battery deal as part of a seven-year fixed-price plan for customers in NSW. It is branded "On".[36] Effectively this is a "lease-to-own" or build, own, operate, transfer (BOOT) model. For example, for customers in Sydney based on high usage (7,500 kWh/year), EnergyAustralia will charge fixed electricity supply rates of 26.9 cents per kWh plus a daily supply charge of $0.73 for seven years.

Nectr – Home Solar + Battery + Energy Bundle

Nectr is a registered trading name of Hanwha Energy Retail Australia, a subsidiary of the South Korean conglomerate that owns solar manufacturer Q.cells. The company is building two solar plants (Jindera, 120MW and Gregadoo, 43MW) in Australia. Last year it also launched electricity retail business Imagina Energia in Spain.

The Nectr product, as with "On", is a solar plus battery system plus retail supply "rent to buy" deal over seven years of electricity bills. Customers are offered Q.cells, Canadian Solar or JA Solar (presumably Nectr makes an additional margin on the Q.cells solar systems).

Nectr quotes the seven-year cost as $15,696 including electricity plan calculation based on cost of system, electricity rate of 24.21c/kWh + 94.81c/day (reference customer usage of 7,500kWh/year) and a feed-in tariff rate of 8c/kWh.

As of April 2021, Nectr stated it had 20,000 customers.

Enel Group – C&I VPP

Enel Group has recently obtained a retail licence for the NEM and subsidiary Enel X already has a 350MW virtual power plant of distributed energy assets including on-site battery storage systems, backup generation and various forms of commercial

[35] The Australian. Mike Cannon-Brookes-backed Brighte makes green energy retail push. 7 November 2021.
[36] EnergyAustralia. Solar Home Bundle. 2022.

and industrial demand response.[37] These flexible assets under management are on more than 150 commercial and industrial sites. Of this, Enel X has registered more than 250MW for participation in the FCAS markets, which it suggests accounts for 15% of cleared FCAS reserves.[38] EnelX was also the first participant in the wholesale demand response mechanism when it commenced in October 2021.

The majority of EnelX's fleet is demand response but it is expanding into owning and operating BESS, including 8MW of batteries for the Central Irrigation Trust (CIT) sites in South Australia's Riverland region.[39] The company is also now offering an electric mobility platform for electric buses and EV charging within the Australian market.

EnelX seems to be the only VPP focused on commercial and industrial customers participating both in the FCAS markets and in the wholesale demand response mechanism.

New Energy Ventures – Modelling of C&I VPPs

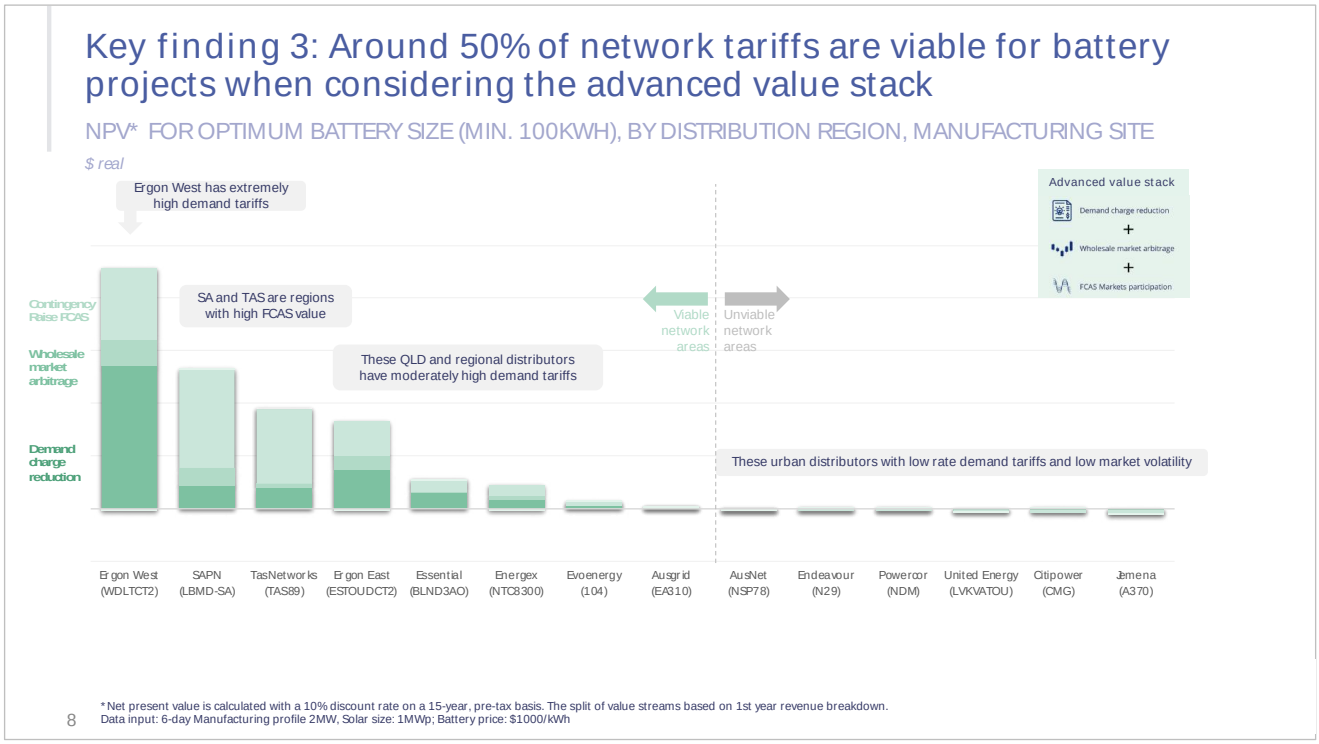
Startup energy management consultancy New Energy Ventures modelled 280 different hypothetical battery projects across the National Electricity Market region for five different C&I load profiles, five state-based wholesale electricity and three FCAS markets, with and without solar PV, 28 different network tariffs with battery operations over 15 years.

The modelling showed, unlike residential batteries and VPPs, the critical importance of demand tariffs in commercial battery projects. In addition, value stacking demand charge reduction with VPP review streams (wholesale market arbitrage and contingency FCAS) would increase the number of viable projects from 25% to 50% out of the sample analysed.

Figure 7 shows how C&I VPPs in Queensland, South Australia, Tasmania, regional NSW (Essential) and the ACT (Evoenergy) are currently viable and the dramatic difference in profitability across these regions, depending not only on network demand tariffs but also available FCAS revenue. The modelling is based on an optimum battery size (minimum 100kWh) for a manufacturing site.

[37] Renew Economy. World's biggest renewables player to create major "greentailer" in Australia. 6 December 2021.
[38] Renew Economy. "Huge milestone" as AEMO switches on demand response in major market reform. 27 October 2021.
[39] PV Magazine. Enel X unveils first Australian battery storage project. 10 December 2021.

Figure 7: Modelled C&I VPP Net Present Value (NPV) by Network Area



Source: New Energy Ventures.

CEP.Energy – VPP Ambitions

CEP.Energy announced in October 2020 that it planned to install 1.5GW of rooftop solar and 1GW of battery storage at C&I sites around Australia over five years. The first stage would be a 400MW "virtual power plant" leasing roof space on properties owned by industrial developer and property owner Pelligra Group with the VPP to be managed by retailer SmartestEnergy, a subsidiary of Japanese conglomerate Marubeni.[40] It is unclear from the publicly available information whether any of the CEP.Energy projects will participate in FCAS markets.

Synergy – Schools VPP Pilot Project

Synergy is the gentailer for all residential and some non-residential customers in Western Australia's South West Interconnected System (SWIS). In 2021, it established a Schools VPP Pilot Project to install VPP technology and infrastructure at 17 schools, including a commercial battery and, where they don't already exist, a solar system. Each school pilot will last for 24 months from the date of installation of the infrastructure and VPP technology.[41] This is an important example of making the best use of DER flexibility, given that schools do not need rooftop solar generation on weekends or during school holidays.

[40] Renew Economy. CEP and Marubeni unveil plans for 1GW battery and 1.5GW of solar in Australia. 21 October 2020.
[41] Synergy. Schools VPP Pilot Project: WA's first VPP. 2022.

The Financial Dynamics of VPPs

Where does all this detailed listing of the VPP trials, the emerging commercially-available VPPs and the insights to date leave us?

VPP trials so far have been costly for the funders with little of the hoped-for consequential increase in scale. Energy Locals and Tesla would have made a profit on their involvement in AEMO demonstrations but it's unclear whether any other aggregators and retailers did so.

From the reports of the VPP trials, we know about the revenue earned but not about any of the costs involved. The economics of VPPs for providers are opaque. We know that there are the following costs:

The economics of VPPs for providers are opaque.

- **Customer acquisition costs:** These will be lower where customers are signed up when they buy a battery (as in the sonnen model) or sign up for finance of a solar plus battery system (as in the Brighte model).
- **Battery and solar capital and installation costs:** These will be lower where there are economies of scale, such as a single provider, for example Tesla for the Simply VPP.
- **VPP aggregation and optimisation platform (software):** This is the sophisticated software for aggregating the DER, optimising the generation, demand response and storage, and working out which markets to export to when, and then implementing all the required algorithms, controls and communications.
- **In some cases, additional hardware:** This may include a device to assist in home energy management (e.g., for air conditioning, hot water), as well as control solar and batteries (e.g., Reposit and SwitchDin's controllers).
- **Losses due to communication outages:** These can amount to up to 8% of data, based on the AEMO demonstrations.

And the following revenue:

- **Customer revenue:** In some cases, this is fixed up-front revenue for the purchase of a solar and/or battery system, or it can be variable – monthly revenue or via retail tariffs.
- **Wholesale price arbitrage:** From high price periods (>$300/MWh), avoiding negative price periods and potentially battery charging in negative price periods.
- **Contingency FCAS revenue**.

Depending on the business model, the following additional revenue could also be relevant:

- **Reduced customer churn:** Lower customer retention costs (if there is a long-term contract; this is particularly relevant for established retailers).
- **Margin on solar/battery sales:** This may apply if the provider is tied-in to specific technology providers.
- **Margin on financing:** Applying to solar+battery as in Brighte's case.

In terms of revenue, it is vital to note the small capacity of existing household batteries, which are often fully charged by 11am. Of all the financial dynamics, the relatively small capacity of household batteries, especially compared with the size of household solar systems, has the most significant impact on the viability of VPPs. This is where electric vehicles could completely change the scale of BTM resources and therefore the magnitude of VPPs (see below).

The relatively small capacity of household batteries has the most significant impact on the viability of VPPs.

There are several potential revenue opportunities for VPPs, all of which are uncertain at this point:

- **A new Fast Frequency Response FCAS service:** To be of less than two seconds, this will commence in October 2023 as a result of an Iberdrola-initiated rule change. [42]
- **VPPs may be able to provide regulation FCAS:** However, this service is only currently available to generators connected to AEMO's Automatic Generator Control (AGC) system, i.e., operation requires a SCADA system.
- **Participation in the Wholesale Demand Response mechanism:** Currently limited to large customers (>100MWh or, in Victoria, >40MWh) and requires the application of a baseline for load consumption at site. A future rule change could allow for aggregated DER participation.
- **Other Essential System Services (ESS):** Inertia and voltage management are being considered as part of the ESB post-2025 market design process but there are a lot of uncertainties.[43]
- **Market or procurement arrangements for Minimum System Load:** If these are put in place to address minimum system load comparable to the

[42] AEMC. Fast frequency response market ancillary service. 15 July 2021.
[43] Energy Security Board. Post-2025 Market Design. December 2021.

RERT for peak demand, aggregated DER may be able to participate.[44]

- **Participation in RERT:** Aggregated DER has participated in RERT trials previously and could do again in future.
- **Local network services:** This is possible but complicated (and will be discussed in a future report).

Figure 8: VPP Costs and Current and Possible Future Revenue

Costs for VPP Provider	Revenue
- Customer acquisition - Battery and solar capital and installation costs - Software aggregation and optimisation platform - *May include additional metering and/or hardware control, including home energy management (eg. for air conditioning, hot water)* - Losses due to communication outages (can be up to 16%)	+ Customer revenue (fixed up-front or variable – month-by-month or by export and/or battery access) + Wholesale price arbitrage (high price periods (>$300/MWh, avoiding negative price periods and potentially battery charging in negative price periods) + Contingency FCAS revenue + *Reduced customer churn and therefore customer retention costs (if customers are on a long term contract)* + *Possible margin on solar and/or battery system* + *Financing of solar+battery (eg. Brighte)*
	Possible Future Revenue + Fast Frequency Response (from October 2023) + Regulation FCAS + Wholesale demand response mechanism (if it was to allow aggregated DER to participate) + Other future Essential System Services (inertia? voltage management?) + Minimum System Load + RERT + Local network services
	** Italics are indication of conditional cost and revenue*

Source: IEEFA.

From the information publicly available from the trials, it's not clear that VPPs are commercially viable at this stage. And as there's no visibility of the costs of VPP establishment and maintenance, the relative competitiveness of VPPs compared

[44] AEMO. Minimum System Load. 2021.

with other forms of generation or demand response is unknown.

However, the large number of commercially-available VPPs suggests that even if profits are not significant yet, retailers and aggregators are looking to ensure profitability over time with scale.

There are trends pushing against future VPP viability over the longer term:

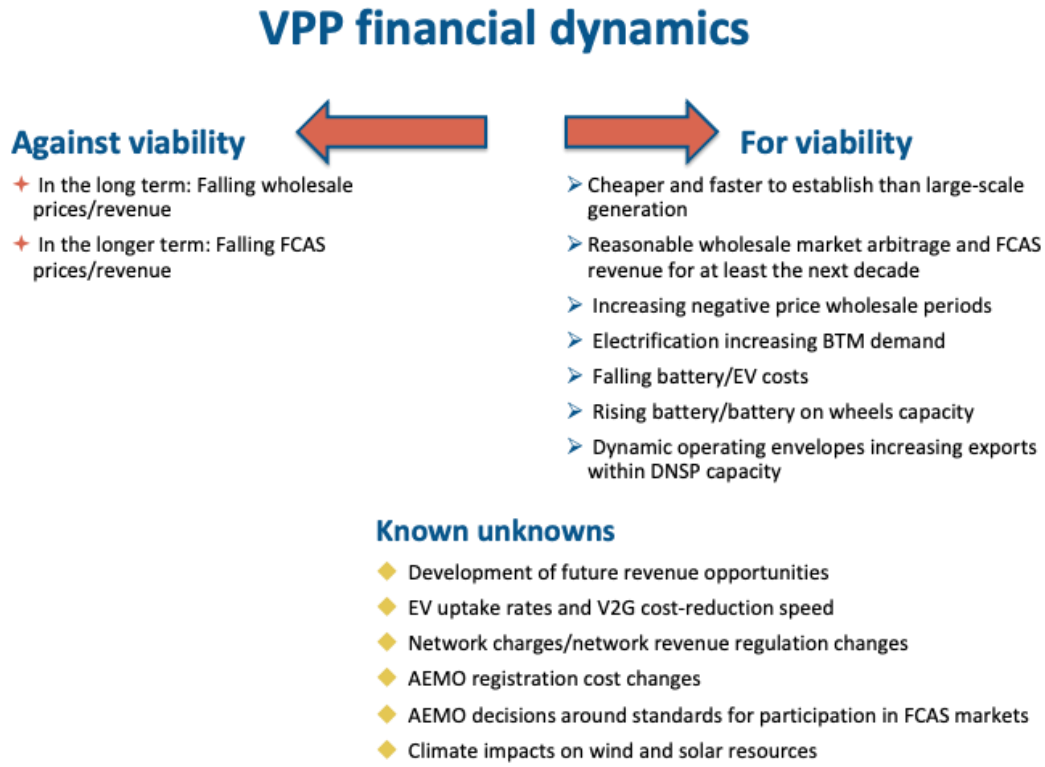
- **Falling wholesale prices/revenue:** This is likely to continue both with increasing negative daytime price periods and reduced peak pricing with increased storage.
- **Falling FCAS prices/revenue:** Especially as more small and large-scale storage enters the system. FCAS costs have been increasing but prices are likely to decline over time as the system is better managed with higher proportions of variable renewable energy.[45] However, FCAS prices may stay high over the next decade given the complexity of managing frequency through the transition.

Meanwhile the dynamics driving towards VPP viability are more significant:

- **Falling battery/EV costs:** It is expected that EVs will be on capital cost parity with internal combustion engines (ICEs) in Australia by 2025.[46]
- **Electrification of transport and gas services**: This will increase BTM demand and storage.
- **Greater revenue from negative price periods:** Anticipated as prices increasingly go negative during the day. This could contribute to less curtailment of solar (and wind) and reduce the need for ramping.[47]
- **Dynamic operating envelopes:** Implementation will increase exports within the distribution network capacity. Recently South Australia Power Networks suggested that dynamic operating envelopes will enable household solar exports to double from a fixed 5kW to a dynamic 10kW 98% of the time.[48]
- **Rising battery and battery on wheels (EV) capacity.**

[45] Joel Gilmore, Tahlia Nolan and Paul Simshauser. The Levelised Cost of Frequency Control Ancillary Services in Australia's National Electricity Market, EPRG Working Paper 2202, Cambridge Working Paper in Economics 2203. January 2022.
[46] BNEF quoted in Drive. EVs to be cheaper than regular cars by 2025, study finds. 25 May 2017.
[47] AEMO. NEM Virtual Power Plant Demonstrations. Knowledge Sharing Report 4. September 2021. 'VPPs assisted in elevating the South Australian operational demand by approximately 5 megawatts (MW) during the record minimum demand period on 11 October 2020, which reduced the severity of the event.'
[48] Utility Magazine. Flexible energy resources key to a low carbon energy future. 28 January 2022.

Figure 9: VPP Financial Dynamics



Source: IEEFA.

Among the significant unknowns for the financial viability of VPPs are:

- **EV ownership rates:** The speed of EV uptake will be highly dependent on the levels of government support.
- **V2G cost reduction speed:** Currently chargers for V2G are of the order of $10,000 and it's not clear how fast this cost will decline.
- **Network charges:** How these will evolve remains to be seen. For example, it's not clear whether distribution-level batteries will be granted a financial advantage through Local Use of System Charges (LUOS).
- **AEMO registration cost changes:** How these will be changed over time is unknown, a cause for concern among some participants in VPP demonstrations.
- **AEMO decisions on standards for participation in the Frequency Control Ancillary Service (FCAS) markets:** There has been significant debate about the Market Ancillary Services Specification (MASS) and technical standards will have ongoing impacts on participants.

- **Climate impacts:** As climate change accelerates, wind and solar resources will be impacted, e.g., rooftop solar generation decreases at higher (>30 degree) temperatures and with increased cloud cover.

Business Models of Commercial VPP Providers

From the review of the commercial VPPs, there seem to be four types of business model that have emerged so far:

Tier 1 Gentailers

These are focused (to some degree) on selling solar and battery systems, hedging wholesale costs and, in particular, retaining customers: EnergyAustralia (VPP contract is for seven years, however this includes lease payments for the hardware), Origin (also has a voluntary household demand response product), AGL (is also hedging negative prices with paid solar curtailment offer for South Australian customers).

Tier 2 Retailer/Gentailers (Usually With a Battery Sales Partnership)

These are retailers who have formed a partnership with a battery or solar provider and/or have a parent company that manufactures or facilitates solar and/or battery sales. These include Discover Energy (parent company One Stop Warehouse partners act as sales fleet), Nectr (sells Q.cells solar systems owned by parent company Hanwha), Simply Energy (until recently only sold Tesla Powerwalls for its VPP, and uses SwitchDin's controller and software), Social Energy (only two battery choices), SolarHub (Tesla only), ShineHub (Alpha ESS battery only).

Aggregator-led

As mentioned above, aggregators manage DER through cloud platforms typically connected to a smart battery inverter or via a smart on-site device. Some aggregators have VPPs in partnership with retailers based on their technology capacity, such as sonnenFlat and sonnenConnect VPP products (for sonnen batteries), and Reposit's no bills VPP (uses Reposit's controller). These aggregator offers are independent of any retailer. Not aggregator-led, members energy (part of Energy Locals) uses Evergen's technology for spot market trading.

Aggregators manage DER through cloud platforms typically connected to a smart device.

Finance Focus

Where financing a buy-now, pay-later solar and battery system is leveraged into a retail VPP contract. This is being done through EnergyAustralia's On Solar Home Bundle product, Discover Energy with Humm Group and LG and is planned by

Brighte (fintech provider that acquired a retail licence in 2021). Effectively this is a BOOT (buy own operate transfer) model where the VPP provider may also make a margin on the financing of the battery solar system.

What is clear is that VPPs are here to stay, especially as the proportion of households with solar is likely to more than double to 70%. The biggest change, for which some VPP providers are already preparing, is the widespread take-up of EVs.

The EV and V2G Game Changer

The combination of rooftop solar and batteries is likely be an interim phase, soon to be replaced by solar and EVs, which have three advantages over stationary storage:

- **EVs have larger batteries.** Most electric vehicles have six to 10 times the capacity of small-scale batteries (and electric trucks and buses have even larger capacity).
- **They are mobile**. Can be driven to charge from different locations.
- **They decarbonise transport**. If charged with renewable energy, EVs can help rapidly decarbonise the transport sector and reduce Australia's reliance on imported oil.

The potential that could be unlocked with EVs is massive. If all 14 million cars in Australia were converted to electric (at an average size of 7kW), this would be 98GW of potential peak output.

Some commentators suggest that Vehicle to Home (V2H) and Vehicle to Grid (V2G) technology (allowing use of the car battery to power the home or export to the grid) is in the distant future and likely to encounter many barriers. Contrary to this argument:

- JetCharge recently announced it was going to begin importing V2G chargers into Australia.[49]
- UK low-carbon electricity producer EDF is already providing V2G for fleet owners of Nissan's LEAF and e-NV200 models in Europe.[50]
- By 2025 Tesla will have standardised bi-directional charging.
- Tesla has taken out a retail licence in the UK.
- The Charging Interface Initiative, an association of Germany's biggest car makers, is working to develop the global standard for charging EVs, including V2H, then V2G.[51]

[49] ABC. EV chargers for V2G and V2H to arrive in Australia within weeks, after long delays. 14 February 2022.
[50] EDF. EDF and Nissan launch new commercial V2G service for EV fleets. 28 July 2021.
[51] Bloomberg. When The Power Grid Runs Low, Your EV's Battery Could Help. 7 June 2021.

By storing power in EVs instead of small batteries, abundant rooftop solar could be unlocked for export around the clock rather than just in the middle of the day.

Aggregators have the potential to start with aggregating the low hanging fruit of commercial EV fleets, as proposed in Origin's VPP plans, discussed below.

VPPs Are the Future of Retail

Solar costs fell 21% per annum in Australia over the 12 years from 2008, from $4.12 per Watt to 17c. The government is now investing in research and development to enable "ultra-low cost solar". The learning rate for battery storage is not as fast as solar but it is still 17%, with costs having fallen 85% since 2010.[52]

Growth in distributed energy resources can only accelerate and EVs will change the system substantially for the better if we implement appropriate charging standards quickly, along with appropriate financial incentives.

The highest value use of DER is always going to be behind the meter, avoiding network and other costs. That is where the bulk of savings will be found and where the majority of DER generation, demand-response and storage will be used. Into the foreseeable future, VPP revenue for customers will be small compared to the BTM savings of solar and batteries.

This accounts for today's relatively small scale VPPs. In 2019, AEMO suggested there would be 700MW of VPPs operating by 2022. We estimate the current total is perhaps 200MW from households (130MW from Origin, the rest from other retailers).

However, while the VPP trials were almost universally unprofitable, as is the nature of trials, the extent of commercially-available VPPs suggests that there are now at least thin margins and that VPP providers (aggregators and retailers) view VPP infrastructure as worthy of investment, especially with an eye to future profits.

Greater profitability from aggregated DER will come from improvements in solar and battery capacity (especially EVs), falling costs and the greater use of DER with demand-response capabilities. It is also worth reiterating that longer-term VPP contracts (such as those for seven years) will reduce costs associated with customer churn.

Into the future, given so much household supply and storage will be BTM, it will be hard for retailers without VPP capabilities to be profitable. Income from sales from the grid will continue to fall, eroding gentailer profitability. At the same time, the volume of exports from DER will increase, creating opportunities for DER aggregators that can harness this fleet for wholesale and FCAS market participation.

After this report was drafted, on 9 March Origin announced plans to expand its 205MW VPP with over 100,000 connected devices to 2,000MW within four years

[52] BloombergNEF. The First Phase of the Transition is About Electricity, Not Primary Energy. 28 January 2020.

from batteries, solar, demand response and EV chargers, supporting the argument put forward here that the future of retail is in aggregated DER. As part of this, Origin aims to have more than 5,000 EVs under management by 2026.

Origin's presentation to investors stated that its in-house VPP "creates lower churn, deeper engagement and seeks to fulfill customers' expectations for lower costs, decarbonisation and energy autonomy."[53] In contrast to my comments about the cost of software platforms and VPP establishment, Origin went so far as to state "VPP assets tend to have very low or even zero upfront capital cost to establish."[54] The difference here of course is that Origin are a large listed company and are making the comparison with the cost of establishing large-scale renewable generators and transmission. Hence Origin comes to the sensible conclusion that "A VPP is a capital and cost-efficient tool to create capacity".

It is also offering an "Origin Zero" product to corporate customers, which includes renewable PPAs, rooftop solar, batteries, EV fleet management, energy management, data analytics and demand response. Origin clearly understands the value of DER and that the future is in offering the combination of rooftop solar, batteries, managed EV charging and being a VPP-tailer for both residential and commercial customers.

Origin clearly understands the value of DER.

Among the financial dynamics, it is vital to remember that DER owners can be just as motivated, if not more so, by social and environmental collective good reasons for participating, and resilience reasons, as they are by minor financial gains.[55] There was some exploration of non-financial motivations, especially helping reduce carbon emissions, through consumer research in the VPP trials and demonstrations, but it remains to be seen how this will play out in commercial VPPs. So far, all seem to be focused on the financial advantages of participation, perhaps with consumers already aware of the emissions-reduction benefits of a solar battery.

Mike Roberts, Sophie Adams, Declan Kuch from the University of NSW interviewed and conducted focus groups with consumers, a total of 37 owners of solar and non-solar systems, and found substantial ambivalence about joining VPPs. They suggest this is because external access to the battery is anathema to consumers who "see a battery purchase as another tool to manage their control over home energy use and their independence from external parties. Asking them to participate in a VPP where the battery is a black box, operated by an external organisation (or its algorithm), whether to maximise their financial benefit or the stability of the network, is asking

[53] Origin. 2022 Investor Briefing. 9 March 2022.
[54] Origin. 2022 Investor Briefing. 9 March 2022.
[55] Monash University. Future Grid Homes. 2019.

them to up-end their understanding of the role of the battery, and their relationship to energy."[56]

Interestingly, the research also found "few participants were enthusiastic about participating in VPP markets with private, for-profit companies. Concerns about equity, fairness and trust were often raised by participants, as well as frustration with the difficulty of negotiating complex options for energy supply." [57] This perhaps suggests an interesting contrast with the commercially-available household VPPs currently run by for-profit companies, perhaps also suggesting a difference between research prior to the fact, about theoretical participation in a VPP, compared with the likely current and future reality where consumers will be offered VPP participation when they buy a battery or by their retailer or through advertising.

From the VPP descriptions and dynamics outlined in this paper, it seems that for the aggregation of DER:

- Revenue is likely to be in infrequent events, rather than daily peaks. More work needs to be done to understand how this might play out, especially as the nature of events is changing with the transition to variable renewable energy. Regions with summer peaks are likely to become winter peaking due to the volume of solar in the warmer months. Events such as South Australia being islanded are likely to be reduced as more transmission is built. The smaller scale of most wind and solar farms compared with coal-fired power stations means outages might not have such a dramatic impact on the system. There is a lot to unpack to find out where VPP revenue will come from.

- Dynamic operating envelopes should increase DER export capacity and so increase revenue.

- Greater use of time-of-use (ToU) tariffs by networks will change revenue dynamics but it's unclear yet how this will play out.

- Flexible loads are vital to make the best use not only of abundant solar in the middle of the day but also match wind abundance and wind droughts. Particularly if aggregated DER is allowed to participate in the wholesale demand-response mechanism -- and if major household appliances have demand-response capability -- then VPPs could be a much more significant source of flexible demand/load. However, there are questions about the extent to which this will be cost-effective compared with large-scale demand response. Further investigation is needed on this.

- The up-front costs of establishing a VPP, especially developing a software platform, are significant for start-ups. Customer acquisition costs can also be significant. Business models of technology or finance providers (such as

[56] Mike Roberts, Sophie Adams, Declan Kuch. VPP User Research Final Report. 27 November 2020. Revised 25th May 2021.
[57] Mike Roberts, Sophie Adams, Declan Kuch. VPP User Research Final Report. 27 November 2020. Revised 25th May 2021.

sonnen and Brighte) reduce the customer acquisition costs when they offer VPP participation as part of a sales transaction.

- In all of this, there is relatively little visible development of commercial and industrial sites' VPPs. Most sites won't be large enough to be market participants in their own right; many will simply match supply and demand behind-the-meter; yet there are no publicly available estimates as to what scale of resource might be available from C&I DER. So far EnelX is the only large commercial player in this space, leaving a remarkably wide-open field for new entrants.

Finally, a word on consumer protections. It is already very difficult for households with solar to compare retail offerings. EVs will only complicate this further. When algorithms control some or all DER, it is very difficult, if not impossible, for consumers to compare VPP offerings. Already consumers have to try and compare a wide variety of VPP offers from 'no bills' to quarterly payments to variable feed-in tariffs and the offers are likely to get more complex, as they have done with bundled internet/telecommunications and electricity/gas offerings in retail.

It is very difficult, if not impossible, for consumers to compare VPP offerings.

The issue of the lack of transparency of algorithms exists in other industries and the Australian Energy Regulator (AER) should consider how the profit sharing between customer and aggregator can be made more transparent and how to provide some means for consumers to compare offers (as is currently required by law through the AER's "Energy Made Easy" comparator website). There is also the question of dispute resolution should consumers be unhappy with how their aggregator has gained access to their battery.

The Australian Energy Regulator should be investigating and considering all these matters (the difficulty of comparisons, the lack of transparency of algorithms, and dispute resolution for VPPs), given its responsibility to inform and protect customers.

At some point the complexity might be such that we reconsider to what extent energy-specific consumer law is needed. Clearly, specific protections are needed for customers who rely on electricity for life support but, beyond that, is the Energy Retail Law becoming irrelevant for DER-dominated consumer electricity services?

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