Project Symphony

Our energy future

Work Package 2.1:

The economic value of a virtual power plant in the South West Interconnected System of Western Australia

Prepared by Oakley Greenwood with input from the Project Symphony Partners

Est. 2008 OGW Oakley Greenwood

In partnership with:

western power synergy AEMO Government of Western Australia Energy Policy WA

Project Symphony
Our energy future

Document Control

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

This draft report was commissioned by Synergy in its capacity as one of the project parties in Project Symphony and provides a cost benefit assessment of the economic benefits that could be provided by the operation of a virtual power plant (VPP) in Western Australia's (WA's) South West Interconnected System (SWIS).

The analysis and information provided in this report was provided by or has been derived in whole or in part from information provided by a range of parties other than Oakley Greenwood (OGW). OGW explicitly disclaims liability for any errors or omissions in that information, or any other aspect of the validity of that information.

Neither this report, or the inputs to it, should be taken to represent the views of Synergy, the Australian Energy Market Operator (AEMO) or Western Power. The report was commissioned, and certain inputs provided on a hypothetical basis, for the purposes of Project Symphony. AEMO provided advice on the Wholesale Electricity Market and public data sets for the development of this report.

The Project Symphony Partners support this report on the basis that it illustrates potential economic benefits of a VPP. However, it should not be considered as the basis for investment, and all parties should undertake independent modelling to inform such decisions.

Project Symphony
Our energy future

Table of Contents

In partnership with: western power, synergy, AEMO, Government of Western Australia Energy Policy WA

1 Executive Summary

1.1 Background and purpose of Project Symphony

High levels of deployment of rooftop photovoltaics (PV) that inject electricity into the grid without any way for their output to be managed present significant challenges to the operation of the power system. Project Symphony, a collaboration between Western Power, Synergy and AEMO, supported by Energy Policy WA (EPWA), will demonstrate and assess the ability of a VPP to assist in ensuring a reliable, secure and affordable electricity system as the installation of distributed energy resources (DER) continues to increase.

VPPs are notional entities comprised of aggregated and managed DER components, which can provide generation, managed load (up or down) and system support functions, and can participate in energy markets (like traditional generators). Project Symphony, which is partially funded by ARENA, will establish a VPP in the Southern River region of Perth, Western Australia. The Project Symphony Partners are aiming to enrol 500 households that will allow the VPP to manage over approximately 900 specific appliances. Appliances that are eligible to be included in the VPP include rooftop PV systems, behind-the-meter (BTM) batteries, electric storage water heating systems (including heat pump water heaters), and reverse cycle air conditioners. The VPP will operate these appliances in ways that can reduce costs and improve reliability and security in the electricity system without any discernible loss of amenity to the participating households.

The specific areas in which the ability of the VPP to create benefits for the electricity supply chain and electricity users will be investigated will include its ability to:

- Reduce costs in the energy and capacity markets in the electricity sector
- Provide a means for managing frequency and other issues in the grid that are associated with the increased deployment of non-firm renewable electricity generation
- Reduce capital expenditure and operating issues in the distribution network that are associated with the increased deployment of unmanaged DER.

Households participating in Project Symphony will receive the equipment required to connect them to the VPP free of charge and other incentives and rewards for their participation.

1.2 The objective of this study

This study has been undertaken to assess the potential impacts of such a VPP if its operation were to be expanded to the entire SWIS.[1]

The study has been undertaken on the basis of the net economic benefits[2] that the operation of the VPP can deliver to the electricity supply system. This basis was chosen because public policy is

[1] It should be noted that another cost-benefit assessment will be undertaken as part of Project Symphony. It will provide the quantitative and qualitative outcomes of the DER integration options tested in the Project Symphony pilot, informed by the pilot's outcomes. As such it is expected to provide an important evidence-based building block to inform regulatory and market reform such as the economic regulatory frameworks of electricity networks. It will also guide market or system design choices to ensure DER is integrated to capture the most value at least cost for the benefit of all consumers.

[2] That is, the degree to which benefits exceed costs.

about maximising benefits to society (i.e., producers and consumers), and this is best achieved through the use of an economic cost-benefit test as opposed to a financial analysis. This is further reinforced by the following considerations:

- Price signals (which determine financial costs and benefits) do not currently exist in the market for all of the services that a VPP can provide to the electricity supply chain,[3] meaning using financial flows may leave out valuing what are otherwise important services, and
- Where the value of a service cannot be monetised (i.e., captured) it is unlikely that it will be addressed by a party acting in its own financial interest.

Cost-benefit analysis is a technique used by business and government that seeks to identify the relative economic value of alternative actions or investments (from a business perspective) or policies or programs (in the case of government decisions). It involves identifying and quantifying (a) the likely benefits of the action, investment, policy or program being contemplated and (b) the costs that would need to be incurred to undertake the action or investment, or to implement the policy or program. Where the benefits exceed the costs, the action, investment, policy or program can be assumed to be cost beneficial. The relative merits of alternative courses of action can also be compared based on their respective net benefit (total benefits minus total costs).

It should be noted that undertaking the study on this basis counts economic costs and benefits only and is not concerned with who bears those costs or to whom the monetary benefits flow. As such, it does not take into account the commercial and/or financial drivers or positions of the individual entities involved and therefore cannot be used to draw conclusions on the potential viability of a VPP as operated by any specific organisation or participation in it by any individual end-use customer.

Rather, the decision was made to conduct the study from the perspective of the economic benefits that a VPP can provide because it will identify the value that can be unlocked by policies and regulations that ensure that price signals exist in the electricity market that reflect those benefits. In this regard it is important to understand that those price signals do not need to be reflected in the tariffs that are seen and paid by electricity customers, and this is especially the case in regard to small customers. Rather, those price signals only need to be available to be acted upon by some party in the electricity sector – for example, a retailer or a third party that can use that price signal as the premise upon which to present a business case to small customers.

In this context, the value of a VPP is two-fold:

- It is an entity that can access price signals in the electricity market that may not be available to end-use customers, and
- It can act as an agent for end-use customers, making it easy for them to allow their end use equipment to be orchestrated in response to the economic value that can provide to the electricity supply system, while also providing a return to the end user without compromising the amenity of their electricity service.

---

3 These services can include ways in which a VPP can reduce the total cost of meeting consumers' aggregate demand for electricity and/or improve the quality, security or reliability of electricity service.

More specifically, the VPP is an entity that can receive, assess and make decisions on the various streams of information that determine whether it is economically viable for customers within the VPP to act in ways that will reduce costs in the electricity supply chain. This information includes but is not limited to (a) real- and near-real time price signals from various parts of the electricity supply system, (b) the underlying demand profiles of participating customers, (c) the status of the various end-use equipment that is under the management of the VPP and (d) upcoming weather conditions that could affect the demand profile of participating customers and their need for electricity. As such, the VPP is able to undertake a degree of information processing and decision-making that few customers would be capable of on their own, even if fully cost-reflective price signals did exist in the retail electricity market.

1.3 Study methodology

The boundary of the analysis provided in this report is the electricity supply chain of the SWIS including the consumer – that is, generators, transporters and consumers of electricity. More specifically, it assesses the net economic benefits that the operation of the VPP can deliver to the SWIS.

Three key assumptions that underpin the methodology used in the study are:

- To the maximum extent possible, price signals are available in the market that reflect the impact that customer consumption and export behaviour has on the costs of the various parts of the electricity supply system,[4] and specifically whether that impact is to increase or reduce those costs.
- Customers will participate in the VPP where it is in their financial interests to do so. Take-up of the VPP was assessed with reference to the financial paybacks observed in customers' take-up of PV systems.
- The VPP does not increase the take-up of DER equipment, but only customers' decisions to allow that equipment to be orchestrated by the VPP operator. Penetration of DER equipment capable of orchestration was based on equipment stock and forecast information provided by the Project Symphony Partners and included: rooftop PV systems, BTM batteries, electric storage water heating systems (including heat pump waters), pool pumps, reverse cycle air-conditioners and electric vehicles (EVs).

It should also be noted that the upfront and operating costs of the VPP were derived from the costs developed for the Southern River VPP. Allowance for cost reductions based on the larger scale of a SWIS-wide VPP as compared to those applicable to the much smaller Southern River region pilot were included. Further reductions were assumed to reflect expected changes in the type of technology used by the VPP and the more general trend of technology costs to decrease over time.

In addition, anticipated reductions in the cost of technology used to communicate with and manage the DER devices participating in the VPP have been included. This includes an assumption that the

---

4 It should be noted, however, that it was not possible to develop a value for every way in which orchestrated DER may be able to provide a service to or reduce costs in the electricity supply system. An example is the Rate of Change of Frequency. The need for this service has only become apparent as the proportion of fossil-based generation in the system has reduced. Although a need for this service has been recognised, methods for quantifying its economic value are still being developed.

Gateway device that is assumed in the costings to serve as the VPP management technology in the first years of operation will be replaced in subsequent years with lower cost application programming interface (API) technology.

Five modelling scenarios were developed against which the economic value of a VPP in the SWIS was assessed:[5]

- base case - no VPP: Assumes that a VPP is not established and the number of PV and battery systems and EVs that are forecast to be installed are in fact installed but are operated without the benefit of cost-reflective price signals or orchestration.
- Scenario 0: Assumes all benefits are monetisable, and the VPP flows all of the monetised benefits to customers. Because this maximises the financial benefit to participating customers, this scenario results in the highest level of customer participation in the VPP.
- Scenario 1: Assumes all benefits are monetisable, and the VPP flows 50% of the monetised benefits to customers. As compared to Scenario 0, this leads to a lower take-up by customers, but it represents a more commercially attractive proposition for the VPP provider and therefore probably a more realistic scenario than Scenario 0.
- Scenario 2: Assumes all benefits except those that apply to the distribution sector are monetisable, and the VPP flows 50% of the monetised benefits to customers. This scenario explores the impact of the absence of cost-reflective price signals and/or regulatory instruments that can effectively facilitate non-network solutions. Under these conditions, there are fewer total benefits that can be provided by a VPP, and because there is less benefit to share with customers, take-up is correspondingly reduced.
- Scenario 3: Assumes that all benefits are monetisable except for the benefits associated with the provision of regulation raise/lower services, and the VPP flows 50% of the monetised benefits to customers. This scenario was undertaken because (a) information provided by the Project Symphony Partners suggested that regulation services may have significantly higher value than other services that could be provided by the VPP, and (b) to date, VPPs in the eastern states have not offered regulation services. As a result, this scenario was undertaken to test the net economic benefits that can be expected to be produced by a VPP where it provides contingency raise/lower services rather than regulation raise/lower services.[6]
- Scenario 4: Like Scenario 1, this scenario assumes that all benefits are monetisable and the VPP flows 50% of the monetised benefits to customers, but it removes the financial cost that VPP customers would face if they allowed the VPP operator to discharge their battery during high-priced balancing market periods, thereby depriving the customer of the ability to use the energy in their battery to offset their own consumption preceding the discharge event. The

[5] It should be noted that the scenarios used in the report were developed independently and have no relation to the scenarios used in the Project Symphony pilot.

[6] Both regulation and contingency services have to do with the ability to respond to and modify frequency in the supply system. Regulation services are needed very frequently to almost constantly, whereas contingency services are needed significantly less frequently. Both must be available at extremely short notice, ranging from sub-second to only a few seconds.

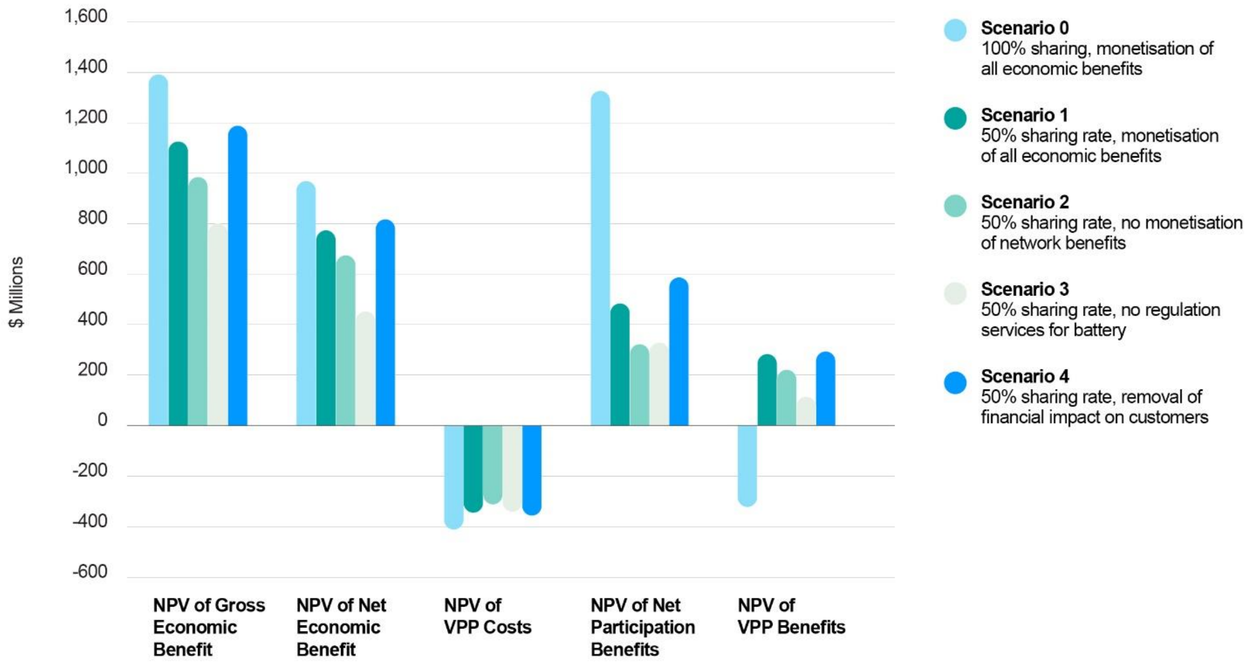
removal of this opportunity cost increases customer take-up. The opportunity cost itself is in part a reflection of the non-cost-reflective nature of current retail electricity tariffs.

The costs and benefits of each scenario were assessed over a 15-year timeframe and are presented in present value terms in 2021 dollars. The study considered participation in the VPP by residential customers only. Small commercial customers would also be likely targets for participation in a VPP, but the diversity of the small commercial sector makes its characterisation in an assessment of this type difficult.

1.4 Findings

Figure 1 summarises the results of the scenarios.

Figure 1: Summary of scenario results



Source: OGW analysis

In relation to the above graph:

- The 'Gross Economic Benefit' reflects the total economic benefit calculated under each scenario, in net present value (NPV) terms, excluding any economic cost associated with implementing the VPP.
- The 'Net Economic Benefit' reflects the gross economic benefits less the estimated economic costs of implementing the VPP, expressed in NPV terms.
- The 'VPP costs' reflects the cost of implementing the VPP, in NPV terms.
- The 'Net Participant Benefit' is the net benefit that accrues to participants (being the providers of the DER devices which are orchestrated via the VPP) under each of the scenarios, which reflects: (a) the proportion of the economic benefit that is assumed to be passed on to them

under that scenario (e.g., the sharing ratio); (b) the upfront costs they are assumed to have to incur in order to participate in the VPP;[7] and (c) except for Scenario 4, the financial (opportunity) cost they face from ceding management of their devices to the VPP operator.

- The 'VPP benefits' reflect the benefit to the VPP provider, in NPV terms, taking into account: (a) the proportion of the economic benefit that they are assumed to retain under each scenario (e.g., the sharing ratio); and (b) the cost of implementing the VPP.

Results of the scenarios can be summarised as follows:

- All scenarios produce positive gross economic benefits. The maximum economic benefit that is produced in Scenario 0 is significant at just over $1.4b over 15 years in present value terms, based on a weighted cost of capital (WACC) of 4%.
- The gross economic benefits decline as we work through Scenarios 1 through 3. This is due to:
  - Scenario 1: Lower customer participation in the VPP due to the application of a lower sharing rate
  - Scenario 2: Lower customer participation in the VPP due to the application of a lower sharing rate and the inability to monetise one of the economic benefits (the network related benefits)
  - Scenario 3: Lower customer participation in the VPP due to lower sharing rate and lower gross economic benefits due to the assumption that batteries are unable to provide regulation raise and lower services.
- In Scenario 4 gross economic benefits increase most of the way back to the level of Scenario 0. This is the result of the removal of a significant source of opportunity cost to the customer, which has the result of increasing take-up.

The maximum net economic benefits of $967m over the 15-year forecast time horizon occur in Scenario 0; they fall to just over $776m and $671m under Scenarios 1 and 2, and down to $453m for Scenario 3.

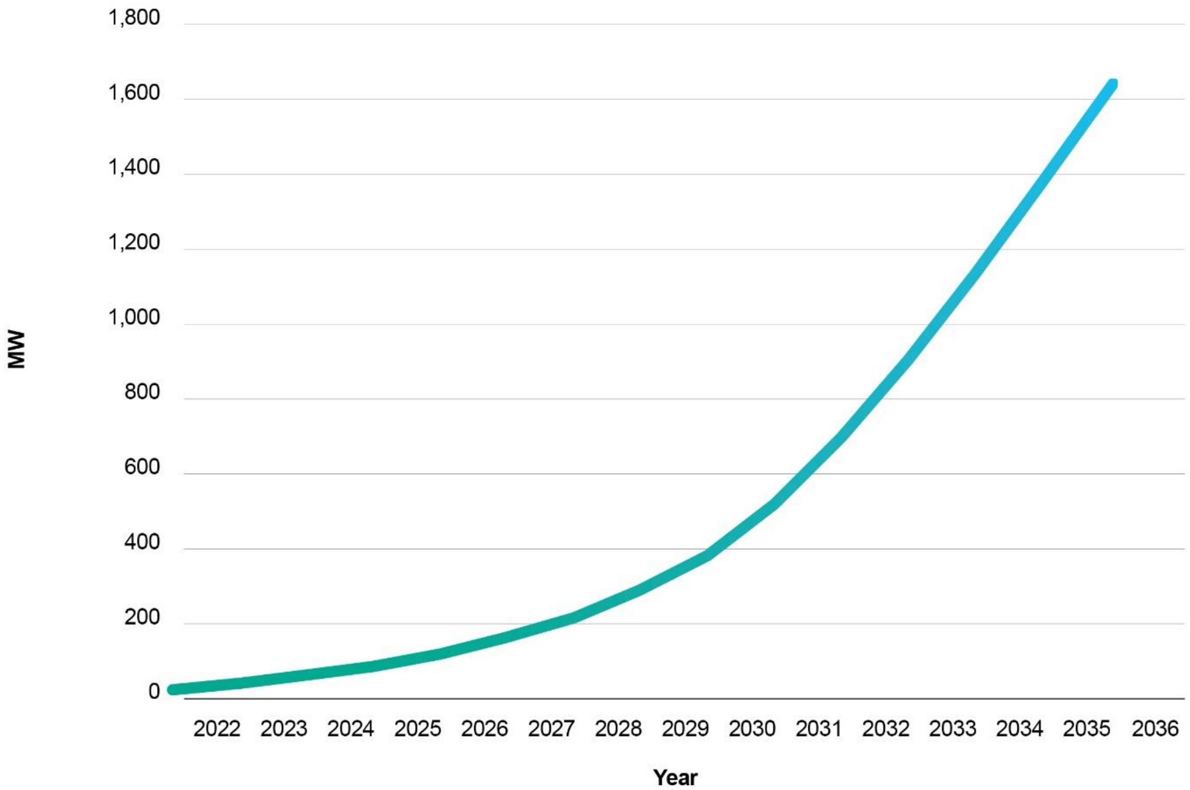
It is also worth noting that the VPP could result in a significant source of new dispatchable generation in the WEM. As shown in Figure 2 below, based on the economic benefits available, the VPP could result in the addition of over 1,600 MW of dispatchable generation/load by the end of the modelling period. For context, it should be noted that peak demand within the WEM at present is about 4,000 MW and Collie, the largest central generation plant in the WEM is about 340 MW.[8]

---

[7] Note that neither the initial cost of the battery (or its replacement at the end of its useful life) nor any maintenance or repair costs associated with its use have been included in this analysis. This is because, in the information provided by the Project Symphony Partners that was used to construct the base case, all batteries included in the assessment were forecast to have been purchased even in the absence of the VPP.

[8] It should be noted that the modelling undertaken in this study only considered BTM batteries. The VPP could also employ direct network connected batteries as part of its portfolio. This may be tested within the Project Symphony pilot.

Figure 2: Total economic potential of VPP-enabled BTM battery capacity (MW) through 2038



Source: OGW analysis

Other key findings are that:

- The BTM battery contributes the majority of gross economic benefits.[9] Therefore, in terms of targeting customers, the BTM battery effectively becomes the gateway to enabling the potential economic operation of a VPP. This is further illustrated by assessing the average economic benefits (i.e., the total economic benefit regardless of the proportion shared by the VPP with the customer) provided by each of the devices.
- Essential System Services (ESS), and regulation services in particular, are the primary contributor to the economic benefits that are generated from a VPP-enabled battery, based on the information provided by the Project Symphony Partners. If VPP-enabled batteries are unable to provide regulation services, the relative contribution that ESS services make to the total economic benefit of the VPP declines materially.
- High levels of unmanaged PV pose significant challenges to system security and stability. Solar curtailment is one way to reduce these potential problems, and measures are being put in place to provide this as a backstop capability when needed for system stability or network reliability purposes. The VPP offers two additional possibilities in this regard. First, by shifting

[9] If the battery cannot provide regulation services (or the VPP decides not to pursue that value stream) it is assumed that the VPP pursues contingency ancillary services – the only difference is the value that can be derived, which affects take-up and therefore total benefit realisation.

load into the middle of the day it has the potential to reduce both the frequency and amount of curtailment needed. In addition, it can provide a means by which households that have PV systems but do not have BTM batteries can provide curtailment as a service with economic value to the electricity supply system.

1.5 Opportunities for value capture

This study has assessed the nature and potential level of economic benefit that a VPP can deliver to the SWIS. Project Symphony will provide information on the real-world factors that influence the degree to which those benefits are likely to be realised and distributed, including the performance and cost of VPP technology, customer take-up of VPP offers, customer acceptance of different types and levels of VPP orchestration, the operation and interaction of policy, market rules and regulations, and the roles and responsibilities of the various parties within the electricity sector.

The analysis undertaken in this study suggests the following items are likely to be important, further considerations regarding the design and operation of a VPP in the SWIS:

- **Targeting battery customers:** As noted above, the modelling indicates that it is the battery that contributes the majority of gross economic benefits of the VPP. Therefore, absent a battery, there is little benefit in targeting a customer for inclusion in a VPP.
- **It will be important to be able to monetise all economic benefits:** Simply put, the more benefits that can be monetised the more value the VPP can offer, which in turn will be likely to increase participation. There are opportunities for increasing the number of benefits that can be monetised by a VPP in both the ESS and network support portions of the value chain. Ideally, Western Power would signal, via a cost-reflective price signal, the value a VPP can provide to their network in the long term. This could be done at a spatial level, and for the avoidance of doubt, these price signals do not necessarily need to flow through to all end customers. The price signal could also be sent via a prudent discount, locational reference service tariff or alternative option contract.
- **Non-cost reflective retail prices, particularly as they relate to the operation of the battery, need to be overcome:** Consideration should be given to ensuring that there are price signals in the market that reflect economic costs and thereby counteract the perverse incentive customers currently have to retain energy in their battery during otherwise high price periods in the balancing market in order to offset their own grid consumption that occurs:
    - Outside of peak (network) demand periods;
    - During periods that generally reflect lower prices in the balancing market, but that are charged to the customer at the same price at all other times; and

  In addition, feed-in-tariffs should be structured and set at levels that reflect the value of energy exported to the wholesale market, including when that export occurs.
- **Attention will need to be paid to VPP technology costs and the potential for reductions in those costs**: The costs in the early years of the study timeframe for setting up and operating the VPP make its net economic benefits marginal. Anticipated reductions in these costs, including controlling technology costs, will significantly improve the VPP's cost-effectiveness over the full study timeframe. It will be important to ensure that developments

in the relevant technology are monitored carefully so that the anticipated cost reductions (or, potentially, deeper ones) can be gained as the technology advances. In this regard it is essential that the ability to exploit new technologies is not precluded by procurement activities that reduce optionality. As an example, the use of API for communications and management when this technology becomes available is expected to provide a significant cost advantage compared to the use of the gateway device that has been assumed to provide this functionality for the first several years of the VPP's operation.

- **The ability to provide regulation services deserves attention in the Project Symphony pilot:** The modelling clearly indicates that the VPP will be cost-beneficial if the only ESS it can provide is contingency control service. However, it also revealed that, everything else being equal, the ability of BTM batteries to provide regulation – and particularly regulation lower service – is likely to be a significant source of value to the VPP and the electricity supply chain. This is due to the significantly higher current and forecast value of regulation lower services as compared to regulation raise services or to contingency raise or lower services over the forecast period. Based on this, the incremental costs of enabling this functionality, and customers' acceptance of allowing their battery to be enabled to provide these services, are issues that should be considered for investigation in Project Symphony or a subsequent pilot.

1.6 Caveats and limitations

It is important to note that the study approach, the model used and the data that was available to the study all have limitations. These should be recognised in considering and interpreting the results. Limitations and caveats include the following:

- The analysis has been undertaken based on a future market scenario projection that has been made at a specific point in time. While the values for each of the specific items being projected (e.g., balancing market prices, essential system services prices, etc), change over the years within the projection horizon, the projections themselves have not been revised to reflect the level of the services and the new demands that would be expected to result from the operation of the VPP as it grows over time. In reality, the actions of the VPP could potentially change those prices, which would then affect the future development of the VPP itself. Capturing these sorts of dynamic interactions is complex and the use of simplifying assumptions such as the use of a single, initial projection is very common.
- Similarly, the model assumes current tariff structures will continue into the future as part of the base case, no-VPP assumption.[10]
- The methodology used to forecast take-up of the VPP arrangement is informed by the payback acceptance levels revealed in the take-up of rooftop PV systems. However, participation in the VPP – that is, how much control the participating customers will be prepared to allow the VPP to exercise over their battery storage systems – is a different matter. We have assumed the battery is able to be exercised by the VPP every day of the

[10] Changes in residential electricity tariff structures and levels (and/or export buyback tariffs) would change the financial attractiveness of the VPP offer as compared to the continued use of an un-orchestrated battery, and therefore take-up. The modelling was undertaken in constant 2021 dollars.

year, and while the level of exercise assumed preserves a margin of the battery that is always available for use by the participating customer,[11] actual operational results when the VPP is implemented may vary from these assumptions.

- The study (and the modelling) focuses only on residential customers for VPP participation. It did not include consideration of contributions that could be provided by end uses or generation sources located in commercial or industrial facilities. Similarly, the study did not consider the VPP owning and/or operating direct network connected batteries despite the potential of such assets to contribute to a VPP's asset structure. As a consequence, the results of the study, in terms of the reported economic net benefits from DER orchestration, are likely to be conservative.
- This study used average seasonal days and prices, an average customer with average electricity consumption and consumption profile, an average-sized PV system and an average-sized BTM battery. In actual practice, different types of customers may find VPP arrangements more and less attractive, which may make a difference to actual take-up and benefit realisation. It could also influence the size of PV and battery systems that are taken up which could also affect the level of benefits realised.
- A further complication to the use of averages was the fact that the total population assumed to be eligible to participate in the VPP was defined as the number of customers forecast by AEMO to install BTM batteries over the study timeframe. It was assumed that those customers could also have the other DER devices that could be orchestrated by a VPP (reverse cycle air conditioning, electric storage water heating and pool pumps). It was also assumed that the availability of the benefits that a customer can derive from enrolling in a VPP would not result in more batteries being installed than the number forecast by the Project Symphony Partners.
- The modelling was undertaken at the SWIS level. This imposed a limitation on the degree to which the model could focus on the benefits that the VPP can provide to the distribution network. Network operating issues and augmentation requirements are all driven by local conditions: the nature of these problems and the solutions to them vary widely from location to location. The SWIS level of analysis precluded the use of locational network cost data for the study.
- While VPP management and dispatch of rooftop PV systems that are not coupled with a BTM battery is technically possible and potentially valuable, this configuration was not included in the modelling undertaken for this report, as explained below.

  One of the primary focuses of the VPP as modelled was its ability to move load into the middle of the day, either through the discharge of the BTM battery or by shifting the time at which the other DER devices are energised. Any such load additions in the middle of the day, all things being equal will serve to reduce the amount that PV export from rooftop systems that are not paired with BTM battery would need to be curtailed.

[11] This was based on information from the actual practice of several VPP operators.

Project Symphony
Our energy future

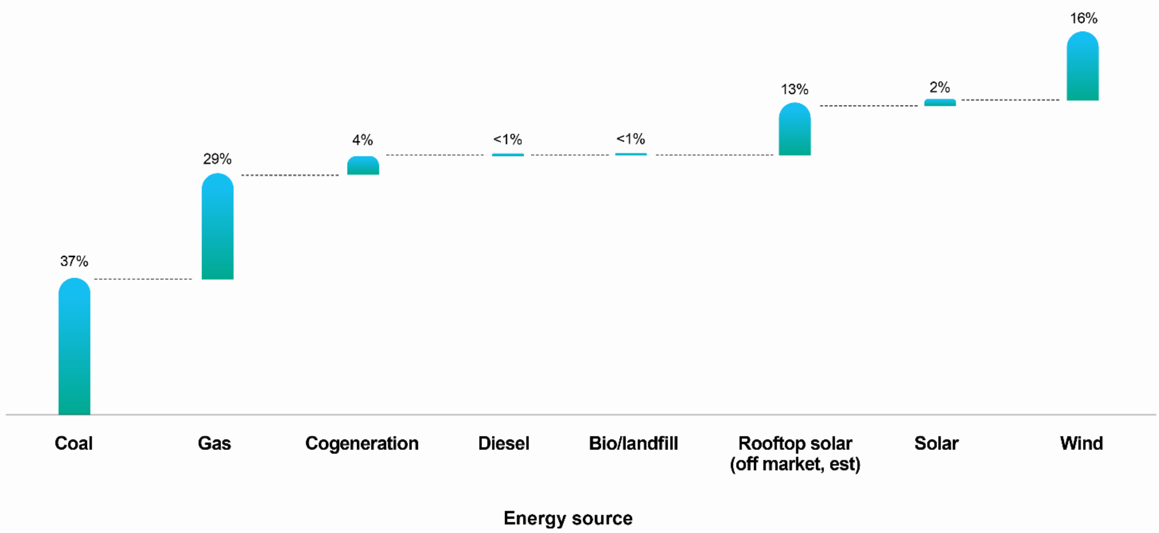
In any case, there are measures planned in WA, as discussed in Section 3.2, that will provide the ability to curtail the export of PV that is not paired with a battery or not participating in a VPP in those instances where that curtailment is needed to protect the stability of the generation/transmission system or to manage reliability and voltage levels in the distribution network.

The deployment of those measures in combination with the VPP, will provide a suite of measures that will enable customer market participation, support further PV growth and reduce the need for last resort measures while providing a backstop to ensure power system security and stability. It may also allow the system to accommodate increased DER capacity and DER generation. To the extent that this potential is realised the analysis presented in this report is likely to be conservative with regard to the total capability that may ultimately be available through the establishment of a VPP.

An introduction to the WA electricity market and the SWIS

- The SWIS is a power grid in the South West of Western Australia. It is not connected to any other large power grids and can be considered a large, islanded power system.
- It is a summer peaking system with maximum energy demand of around 4GW, which has been stable for several years as the impacts of behind the meter solar PV and energy efficiency has mitigated natural growth and moved system peaks later in the day.
- The SWIS is a very peaky system, with distributed solar PV driving low midday operational demand and corresponding rapid ramping requirements to meet for the evening peaks.
- On-market energy (excluding rooftop solar PV) for FY21 was around 17.5 GWh.
- Distributed solar PV is growing rapidly and now has a maximum output capacity of around 1.7 GW making it the largest single source of generation by capacity. It is expected to continue to grow over the 15-year period covered in this report.
- While the SWIS has day ahead, short-term energy market (STEM) and a gross pool balancing market, 80%+ of energy is traded through bilateral contract.
- The SWIS runs a reserve capacity mechanism to ensure that there is sufficient generation capacity to meet peak demand. This means that availability payments are made to generators in addition to energy sales revenue.
- The SWIS has a State-owned gentailer (Synergy) for most residential and other small use customers, with retail tariffs for these customers set by government. Larger customers are contestable with competitive tariffs.
- The network covers a large geographic area with over 50% of the high voltage overhead network servicing around three per cent of customers.
- The contribution of energy sources to total energy output in 2020-21current fuel mix is provided in Figure 3 below.

Figure 3: Generation fuel mix 2020-21



Source: EPWA analysis

2 Background

The rapid growth in DER, while delivering significant financial and environmental benefits, is leading to a range of emerging issues for network operators, system operators and ESS providers.

Currently, one in three households in Western Australia have rooftop solar. This represents ~1.7 gigawatts of passive, renewable energy generation, representing the largest source of generation on aggregate connected to the electricity distribution system on the SWIS.

Rooftop solar as a source of 'cheap and clean' renewable energy generation is growing rapidly, and predominantly being connected to the low voltage distribution network which is 'at the opposite end' to the centralised, high voltage transmission network with connected large fossil fuel-based generators that has characterised the electricity supply chain until quite recently.

Growth in largely consumer-owned DER will increase as the market for rooftop solar continues, and accelerates for customer battery storage, along with EV charging, smart home energy management systems and demand response initiatives involving larger appliances such as air-conditioning and swimming pool pumps.

It is well documented that a high penetration of DER, particularly rooftop solar, poses a significant risk to the stability of the power system at times of low system demand caused by an excess of local, unmanaged or passive customer rooftop solar with low corresponding demand for electricity. This has a propensity to occur during cooler, yet sunny days when solar generation is high, but electricity demand is low due to little or no cooling load from air conditioners etc. AEMO anticipates there will be material risk to the stability of the SWIS by 2024 if DER is not efficiently and effectively managed.[12]

Project Symphony is an innovative project (the Project) where customer DER like rooftop solar, battery energy storage and other major appliances, like air conditioning and pool pumps, will be orchestrated as a VPP to participate in a future energy market and unlock greater economic and environmental benefits for customers and the wider community. A collaboration between Western Power, Synergy and AEMO, supported by Energy Policy WA, the project aims to understand how the opportunities and challenges of increasing DER can be managed to ensure a reliable, secure and affordable electricity system.

2.1 Key objectives

A key objective of this report, Work Package 2.1 of Project Symphony, is to develop an understanding of the economic value that can be created by DER and the extent to which that value can be effectively captured and monetised by commercial entities and DER providers. It involves:

- Identifying DER value streams and constructing DER scenarios.[13]

---

[12] AEMO, Renewable-energy-integration: SWIS update.

[13] Note that Project Symphony refers to the testing of DER pilot 'scenarios'. For this work we developed DER 'value streams', which reflect the ways in which the use of DER can provide benefits (i.e., value) to the electricity supply chain, a source of revenue (or savings) to DER host facilities, and a business proposition and revenue stream for aggregators including a means for building customer loyalty and retention for a retailer/aggregator. Where we use the term 'scenario' it refers to the construction and modelling of the value creation and value capture of one or more DER value streams.

- Quantifying the value of the various DER services.
- Identifying and quantifying core barriers and challenges that may prohibit value capture of a particular DER value stream.
- Considering possible conflicts between different DER value streams as well as conflicts and barriers with current price signals.
- Identifying the risks and role of DER in the wholesale market, focusing on wholesale energy, including the potential for DER to impact net contract positions managed in the wholesale energy market.

2.2 Developments in the SWIS

The WEM of the SWIS is evolving with new market rules to take effect from October 2023. As a result, the data and assumptions developed for the modelling project are based on the current WEM design, but the model transposes the information into the various new elements in the WEM.

Because the technical operational details of the market for services for managing the rate of change of frequency (RoCoF) in the WEM are still to be fully detailed, the potential value of that service being provided by a VPP has not been included in the modelling.

3 Methodology and Assumptions

3.1 Methodology

This study provides a cost-benefit analysis of the potential economic value of the operation of a VPP in the WEM.[14]

Cost-benefit analysis is a technique used by business and government that seeks to identify the relative value of alternative actions or investments (from a business perspective) or policies or programs (in the case of government decisions). It involves identifying and quantifying (a) the likely benefits of the action, investment, policy or program being contemplated and (b) the costs that would need to be incurred to undertake the action or investment, or to implement the policy or program.

Where the benefits exceed the costs, the action, investment, policy or program can be assumed to be cost beneficial. The relative merits of alternative courses of action can also be compared based on their net benefit (total benefits minus total costs) or the degree to which the costs incurred leverage the benefits received (total benefits divided by total costs).[15]

Qualitative factors can be discussed, but obviously cannot be included in the CBA arithmetic. Benefits and costs that cannot readily be monetised (e.g., satisfaction, happiness, inconvenience) or for which there are not generally accepted monetised values (e.g., the monetary value of reducing carbon emissions) are often included as additional, and in many cases, qualitative factors in cost-benefit assessments. However, the inclusion of these types of costs or benefits requires the use of additional (non-arithmetic) means to be used in determining whether a particular course of action is in fact cost-beneficial or which of a set of alternative courses of action is the most preferred.

The cost-benefit assessment conducted in this project was undertaken primarily from an economic – rather than a financial or an operational – perspective. The economic assessment counts economic costs and benefits (quantified in dollar values) only and is not concerned with who bears those costs or to whom those benefits flow. As such, it does not take into account the commercial and/or financial drivers or positions of the individual entities involved and therefore cannot be used to draw conclusions on the potential viability of a VPP as operated by any specific organisation, or participated in by any individual end-use customer.[16] The report does, however, provide an example of how the economic costs and benefits might be distributed to the various parties to and affected by the operation of a VPP, under the assumption that those economic benefits can be monetised and assumptions about how the VPP would share those monetised benefits with the end customers participating in the VPP.[17]

---

14 The study assumes the VPP is operated by Synergy.

15 Generally referred to as the benefit-cost ratio.

16 The only exception to this is in the calculation of the number of DER customers that could be expected to participate in the VPP. This is done by assessing the financial return to the customer from participating in the VPP arrangement as compared to not doing so. The financial return itself, however, is calculated using the economic costs and benefits of taking up the VPP offer or not.

17 Providing complete information on the projected financial outcomes of a VPP would require detailed information about the commercial position of the VPP operator and about the customers it was seeking to enrol. It would essentially constitute a business case, and its outcome would rely on the price signals available in the electricity market. This study has used the economic value (not the actual price impact) of changes in end consumers' electricity export and consumption behaviour and explores a range of scenarios defined by assumptions about the extent to which economic benefits can be monetised and the extent to which those benefits are shared

More specifically, the economic perspective counts:

- as ***a benefit***, anything that reduces costs in the electricity supply chain because any such cost reduction should, in economic theory, serve to reduce costs to consumers, due to efficient regulation, and
- as ***a cost***, any expenditure undertaken as part of the effort to create the benefit, including, where quantifiable, any loss in amenity or service quality due to that effort.

In practice, only a market body (government, regulator, system operator or market rules maker) is likely to pursue economic benefits when those benefits are not expressed in the price signals that exist in the operation of the market. Customers and electricity sector businesses (generators, network operator, retailers, aggregators and third-party energy management companies) will react to the price signals in the market that affect them – and this is rational behaviour. Where those price signals reflect how the energy consumption or export behaviour of the consumer affects costs in the electricity supply sector, the rational behaviour of those parties will be aligned with economic benefits and costs.[18]

It is important to note, however, that this behaviour can occur even where those price signals are not delivered directly to end customers in network tariffs, retail tariffs or market offers. This is because the existence of those price signals in the market provides a value proposition for any business that can assist the consumer in acting in concert with those economic price signals by making it easier for the customer to do so and then sharing the benefits available. This is the basis on which we have undertaken the cost-benefit assessment of the value creation and capture of a large-scale orchestration of DER.

Illustrative results regarding the implications of how the economic benefits of VPP operations could affect overall results were explored through a set of scenarios that (a) varied the split of VPP benefits between participating customers and the operator of the VPP, and (b) included and excluded various benefit streams. The composition of these scenarios is discussed in Section 4.2.1.

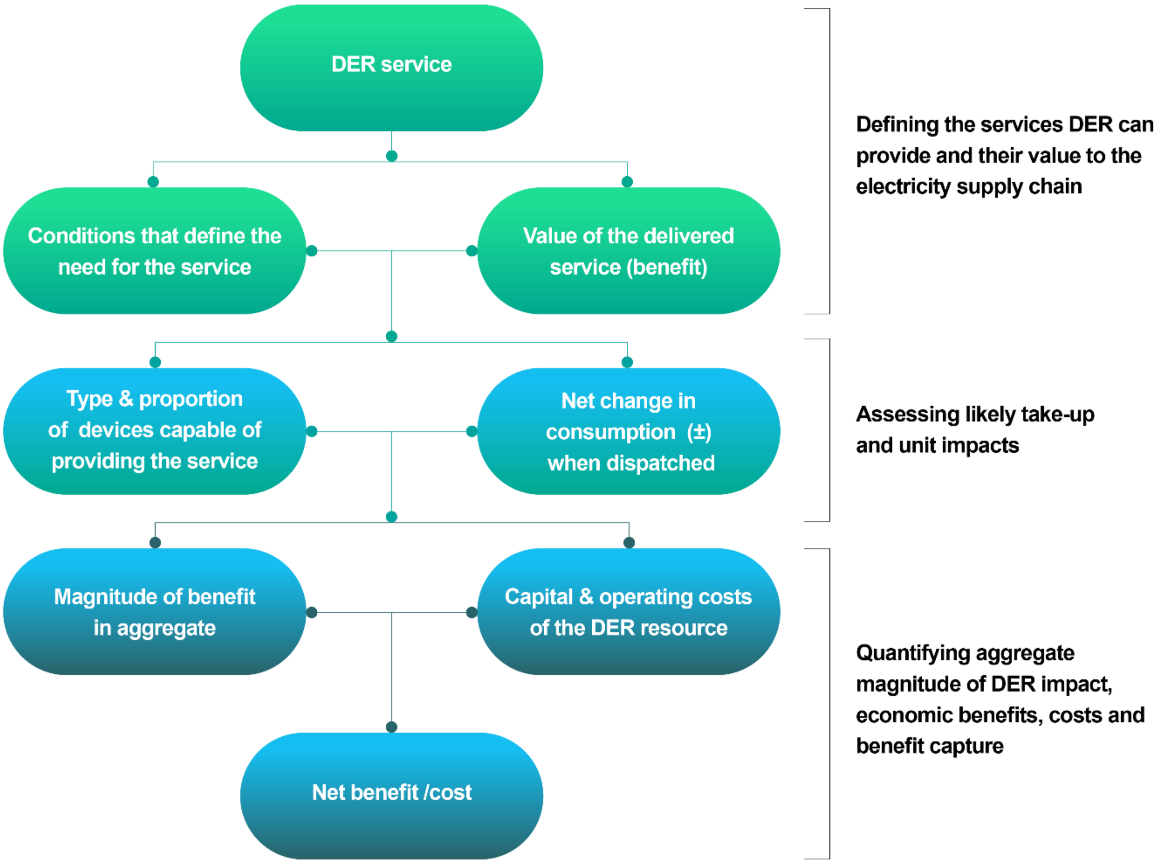
An overview of the conceptual framework used in the methodology is shown in Figure 4 below. The methodology used reflects the purpose of this project, which is to determine whether the expected economic benefits of a VPP are likely to outweigh the costs that would be incurred in establishing and running the VPP. If so, further consideration will be warranted to determine what needs to be done to align financial outcomes with economic benefits, such that those benefits can be realised at the levels required by the parties involved. The key result of the analysis entails a comparison between a non-orchestration base case with the net benefits of a VPP scenario case. The magnitude in the difference between these cases and the sign of the difference are the primary focus. Small differences in economic benefits between the scenarios should not be interpreted as providing a definitive ranking.

---

between the VPP operator and its end-use customers. The financial flows to the various parties involved in or affected by the VPP for each scenario are provided in Section 4, but that information should be seen as illustrative only.

18 It is important to note in this regard that consumers' electricity consumption and export behaviour can reduce costs in the electricity supply chain as well as impose costs. Cost-reflective price signals make this apparent as they reward consumer behaviour that reduces costs.

Figure 4 - Conceptual framework used in the methodology



Note: A DER service is a change in the consumption or export of an individual or an orchestrated group of end-use customers that is enabled by the presence of a distributed energy resource (DER) and is undertaken in response to a price signal available in the electricity value chain.

To understand the potential net benefits that can be created by the VPP, we have assumed that price signals exist in the SWIS that reflect the economic impacts of consumer consumption and export.[19] This simulates an efficient market environment which may differ from the actual market environment. An analysis undertaken on this basis reveals the potential economic value of activities that seek to align consumer behaviour with the costs of the electricity supply chain. To the extent that consumers, or parties acting as their agents (retailer, aggregators or other third parties), cannot monetise those economic benefits – that is, cannot realise those benefits in financial terms – it is unlikely those economic benefits will be delivered except insofar as they are the by-products of actions addressing other signals.

[19] Note that these price signals do not need to be reflected in consumer's tariffs – but they need to be available to and monetisable by some party – a market participant of some sort in order for the associated benefits to be realised. Otherwise the benefits remain entirely theoretical.

As an example, consider one way in which consumer behaviour can affect costs in the distribution network. The take-up of rooftop PV systems can lead to over-voltage conditions at times when the amount of export from those systems exceeds the consumption requirements of loads in the local area. This is most likely to occur on mild sunny days in residential areas where there is a significant level of PV penetration. On those days (typically in spring or autumn) consumption will be relatively low, due to the near total absence of space heating or cooling loads, and PV export will be high. Such conditions lead to voltage rise that will require some means of lowering the voltage or increasing the capability of the local area network to manage that voltage.

There are a variety of ways of addressing this, including:

- Limiting network access – this is already being done in some places by not allowing additional PV connections in areas of the network where these problems exist or are anticipated to exist in the near term. However, this does not help where the problem is the result of PV systems that are already in place. In some cases, the inverter in the PV system may be able to be managed under such conditions, but this is not the case for most older PV system inverters.
- Curtailing exports – with appropriate communication protocols in place, newer PV systems may be able to be managed to limit PV exports in response to over-voltage or low demand conditions on the network. Project Symphony will be testing this capability through the application of dynamic operating envelopes (DOE) and a pre-emergency 'constrain to zero' scenario.[20]
- Increasing the hosting capacity of the network – this raises the question of how the associated costs should be allocated.
- Providing a price signal – the ability to avoid the cost that would be required to increase the hosting capacity of the network in a local area could be used as the basis for a price signal. On one hand, it could be used to create an export charge that would signal the cost to customers with PV systems. The cost would only be applicable at times when export volumes create over-voltage conditions or approach thermal constraint levels. Acting rationally, those customers would then compare that cost with the benefit they would receive from their export, and act accordingly.
- Alternatively, or in addition, the network could consider providing a prudent discount to network users (e.g. retailers) that facilitate an increase in their load at these times as a means for soaking up the excess PV export. The level of the prudent discount could reflect the cost that would be avoided by the network not having to increase hosting capacity in the local area. The effect of such load additions would be to reduce the amount of curtailment that would be needed.[21]

---

[20] This option might raise the issue of whether customers whose exports are constrained should be compensated for loss of revenue they would suffer. It should be noted however that compensation of the foregone revenue is unlikely to reflect the avoided cost to the network of the constraint of export.

[21] Examples of how increasing load and/or the use of BTM storage can help in this regard include charging the battery or turning on air-conditioners or pool pumps. In essence, more load during these times will allow the voltage on the network to be managed via transformer tap changers and the use of reactors. A functioning bi-directional market can be an important part of the response to managing negative wholesale energy prices.

In the absence of these price signals, PV customers will continue to export whenever the amount of energy being generated by the PV system exceeds the energy demand of the host facility.[22] By contrast, where such price signals are put in place, customers — or their agents — are likely to consider actions to benefit from those price signals. For example, a retailer or a VPP might offer to shift schedulable loads - such as water heating, the use of pool pumps or the charging of BTM batteries - to those times.[23]

This cost-benefit assessment assumes that price signals that reflect the costs of consumers' consumption and export behaviours exist throughout the supply chain. In this analysis, the VPP undertakes actions in response to these price signals and creates an economic benefit. If, in the real world, such price signals do not exist, this activity would still create a benefit, but the VPP, acting in its own commercial interest, would be disinclined to undertake that activity because it would not result in any financial benefit to the VPP or the customer because the activity would not be able to capture (i.e., monetise) the benefit.

3.2 The electricity system context that was modelled

Due to the forecast continued strong growth of PV systems, the SWIS will soon encounter low system demand and reverse power flows in more and more parts of the network. This will require additional measures to maintain system and network security.

A VPP provides a mechanism for procuring cost-effective market services that can assist in maintaining system security (via ESS) and network security (via a network support service). A VPP also enables capture of upstream market benefits through retailer energy trading.

However, there may be occasions where system and network security cannot be maintained through procurement of paid market services (noting that the need for such services is likely to arise in the relative near-term and the establishment of a VPP is only in its early stages). In such cases, independent non-market measures would be needed. Three such measures are already planned for use in WA:

1. Mandatory capability for new and upgraded rooftop PV systems below a certain size to be subject to emergency solar management (ESM), which will enable curtailment of PV systems in response to system demand reaching a specified minimum threshold (proposed to be implemented in 2022).

[22] Note that (a) the only exception to this would be where the customer's PV system is mandatorily constrained from exporting, and (b) the same issue arises where the customer has a PV system with battery storage that cannot be orchestrated. In this case, the problem is buffered by the battery – but only to a degree; once the battery is fully charged any additional energy generated by the PV system will be exported without control to the grid. Experience has shown that this buffering effect only results in the delay of this problem for a few hours on mild sunny days.

[23] Western Power currently offers entry services to distribution and transmission connected generators with associated reference tariffs based on sent-out capacity. However, entry (bidirectional) reference services offered by Western Power to small use customers do not currently apply generation-based reference tariffs, only consumption-based tariffs. The price signals contemplated in this report would provide ways that customers' needs for network services could be funded in an economically efficient and equitable manner, based on the costs those activities would impose or reduce on the network (and therefore all other customers). They would also allow any additional benefits provided by those exports to be realised.

2. Dynamic operating envelopes (DOE) which set maximum import and export limits for customers at the National Metering Identifier based on local network capability and conditions (being tested within Project Symphony to inform future deployment).
3. Export limits for larger PV systems that do not have export agreements or are participating in VPP arrangements (proposed to be implemented in 2022).

In combination, VPPs, ESM and DOE provide a suite of measures that enables customer market participation, supports further PV growth[24] and reduce the need for last resort measures (including load shedding and autonomous power quality responses by DER inverters) while providing a backstop to ensure power system security and stability. DOE has the potential to also expand DER import and export capacity during periods of low network risk.

The decisions to undertake the ESM and DOE have already been made and the VPP as modelled in this report does not rely on those decisions or the technology to be used in implementing them. As a result, the VPP as analysed here has been undertaken on a fully independent basis and references to VPP in this report do not include any costs or benefits associated with the ESM or DOE, nor has any assessment been made of the costs and benefits of those policies.

3.3 Overview of the model

As noted above, the model is designed to calculate the economic benefit to the electricity supply system resulting from orchestration of DER through a VPP and the economic cost required to establish and operate the VPP. The analysis assumes the VPP commences operations in 2021 and operates for 15 years.[25]

3.3.1 The nature of the VPP assumed

The modelling assumes and is limited to a VPP that focuses on orchestrating the DER of residential customers who have BTM battery storage systems[26] and other end-use equipment whose operations can be managed without material impact on the service or amenity they provide to the household.

The specific DER devices that are assumed to be able to be orchestrated as part of the VPP in the modelling are:

- BTM batteries (which are assumed to be paired with rooftop PV systems)[27]
- Reverse cycle air conditioners

---

24 An important potential benefit of a VPP is its ability to avoid the need for blunt tools for protecting system security such as prohibitions on PV connections in specific areas. This is consistent with WA government policy which is to accommodate the growth of the use of rooftop PV and other DER.

25 This was considered by the Project Symphony Partners to be a reasonable timeframe given the lifetime of the relevant assets and the horizon over which the decision to establish such a business would likely be made. Note that no continuing benefits or terminal value are included in the cost-benefit analysis.

26 A BTM battery provides a significant source of flexibility in the customer's ability to consume or export energy. This flexibility is a key source of the potential economic value of the VPP to the electricity supply chain. The analysis also considers the management of other loads within the home, but the battery comprises the greatest source of value to the VPP and electricity supply chain, and therefore to the customer.

27 Direct network connected batteries could also be owned or operated by a VPP. This may be included in the Project Symphony pilot but has not been considered in this analysis.

- Pool pumps
- Electric vehicles (as a dispatchable load only)
- Electric storage water heaters (including heat pump water heaters).

The total population assumed to be eligible to participate in the VPP was defined as the number of customers forecast by AEMO to install BTM batteries over the study timeframe.[28] It was assumed that those customers could also have the other DER devices listed above.

It should be noted that while VPP management and dispatch of rooftop PV systems that are not coupled with a BTM battery is technically possible and potentially valuable, this configuration was not included in the modelling for the following reasons:

- One of the primary focuses of the VPP as modelled was its ability to move load into the middle of the day, either through the charging the BTM battery or by shifting the time at which the other DER devices are energised. Any such load additions in the middle of the day, all things being equal will serve to reduce the amount of PV export from rooftop systems that are not paired with BTM battery that would need to be curtailed.
- In any case, there are measures planned in WA, as discussed in Section 3.2, that will provide the ability to curtail the export of PV that is not paired with a battery or not participating in a VPP in those instances where that curtailment is needed to protect the stability of the generation/transmission system or to manage reliability and voltage levels in the distribution network.

The deployment of those measures will provide a platform that will assist in the integration of those systems within a VPP, and to that extent, the analysis presented in this report is likely to be conservative with regard to the total capability that may ultimately be available through the establishment of a VPP.

3.3.2 Estimating customer take-up of VPP arrangements for BTM batteries

A key aspect of the model is a calculation that determines the proportion of customers with BTM storage that choose to join the VPP.

Whilst there are different approaches to forecasting the take-up of a new demand-side energy technology, such as BTM battery storage or the conversion of an existing BTM to VPP-enabled battery storage, virtually all of them include some consideration of the financial attractiveness of the technology to prospective purchasers.

To this end, we have relied upon the revealed behaviour of a similar technology - residential rooftop PV systems – to assist us in considering the Scenario 0 forecast of BTM batteries (which was provided by the Project Symphony Partners) that will be converted to a VPP-enabled battery.

---

[28] See AEMO's 2020 inputs and assumptions for the WEM Electricity Statement of Opportunities. We note that the benefits provided by the ability to participate in a VPP could result in even more customers taking up batteries, but this was not modelled and the results of the study may be conservative in that regard.

More specifically, we have relied upon an estimate of the first-year return on investment (RoI) of rooftop PV systems over the last 3 years, adjusted down to reflect an assumption that customers are likely to be at least somewhat reticent (even where they can expect to benefit financially) to cede management of their battery to a third party, given:

- Uncertainty concerning the impact of VPP operations on battery charge/discharge patterns (and hence the customer's ability to utilise the battery for the purposes of offsetting their retail bill, which would have been the main reason why they invested in the battery in the first place)
- Potential concerns regarding the impact that the VPP's operation of the battery might have on the life of the battery
- The more complex business model associated with a VPP, as compared to investing in PV or PV and battery on its own.

The first year RoI is then applied to the estimated financial benefit that accrues to battery storage upon its conversion from a BTM battery to a VPP-enabled battery. This financial benefit reflects:

- The stream of financial benefits that are assumed to flow to the owner of the VPP-enabled battery as a result of allowing the VPP operator to manage the battery at certain times of the day, week, month and year. This reflects the gross economic benefits, multiplied by the assumed sharing of those benefits with the battery owner; less
- The opportunity cost to the owner of the VPP-enabled battery resulting from having to allow the VPP operator to manage the battery. This reflects the fact that the VPP operator might operate the battery in a way that leads the owner of the battery to have to consume more energy from the grid, at retail prices, which is a cost they incur, relative to if they choose to not allow the VPP operator to provide that management.

This same approach has been adopted for all the DER devices modelled (e.g., air-conditioners and pool pumps).

For the avoidance of doubt, the model assumes that the maximum take-up of any of the non-battery device as part of the VPP is limited (or capped) at the number of batteries that are assumed to be enabled in the VPP in that year. So, for example, if the number of VPP-enabled batteries is 10,000 in a year, no more than 10,000 air-conditioner loads, pool pump loads, etc., could be converted to be part of the VPP. Implicitly, this means that the VPP operator would not enable any of the other devices *without also enabling a battery at that same site*. Finally, we have not assessed the likely mix of devices at an individual VPP site. The implicit assumption is that:

- Every customer in the VPP has a battery; and
- Every one of those same customers has all the other DER devices (other than EV chargers) that are assumed to be taken up in that year.

3.3.2.1 Economic benefits considered

Table 1 provides an overview of the economic benefits included in the modelling.

Table 1: Overview of the key economic benefits quantified in the modelling

Benefit category	Comment
Balancing market economic benefits	Economic benefit stemming from being able to: • Move consumption from high-cost periods to low-cost periods; or • Charge a battery at low-cost periods and discharge it in high-cost periods. The balancing market is assumed to reflect the short-run marginal costs of the supply in each half hour period, hence it is the appropriate price signal[29] upon which to estimate the economic benefits that would result from the above changes.
ESS economic benefit	The use of VPP resources to manage frequency deviations (and to provide other services to support power system security). The battery — when charged — can be discharged and loads under management can be switched off to provide a frequency raise service. The battery — when discharged — can be charged and loads under management enabled to provide a frequency lower service. Two forms of frequency management are included in the model: • Regulation services — automatic generation control (AGC) enabled services can be supplied by storage devices. Regulation lower is enabled when the battery has been discharged to some degree and is therefore capable of being charged. Regulation raise is enabled when the battery has sufficient charge and is therefore capable of being discharged. Regulation services are used quite frequently in the normal course of market operation. • Contingency services — these services are paid for being available (referred to as enablement) but are called relatively infrequently. The lower service is enabled for devices that are not fully charged or are able to absorb energy, while the raise service is enabled for devices that can be switched off or can export energy. Other ESS — notably RoCoF — are not quantified in the model as their technical operational details have not yet been defined in the WEM and no information is available at this point on how often it is likely to be needed or its value in the WEM.[30]

[29] As opposed to the STEM or bi-lateral contract market, as these may not necessarily reflect the true economic costs and benefits to the industry.

[30] Further information on these ESS and the reasons for them not being included in the modelling is provided in Appendix A.

Benefit category	Comment
RCM (capacity supply-side) / IRCR (capacity obligation-side) economic benefits	The benefit that could be derived through the reserve capacity mechanism (RCM) is modelled, as a battery can be offered into the RCM as a capacity provider, subject to specific availability requirements. Note that where an RCM benefit is included, the storage device must be enabled for each of the real time markets (RTM) — i.e., the balancing and frequency control essential system services markets — and the STEM[31] during a defined period. The total individual reserve capacity requirement (IRCR) benefit that may accrue to wholesale market customers if the storage cannot be used in the RCM is not directly modelled but will be equivalent to the value of the RCM benefit that has been modelled.[32]
Network support benefits (both for peak demand and over-voltage conditions):	Network support services (i.e., management of constraints and voltage in the distribution system) are modelled where they can avoid augmentation costs or maintain or improve network service levels.[33] Solar curtailment is one means for providing network support but has not been included in the scenario modelling, as discussed earlier in this section of the report.

3.3.2.2 Calculating the impact and value of DER orchestration

As we are assessing the economic impact of orchestrating a device as part of a VPP, we had to estimate how that device might be operated if it were to be included as part of the VPP. As such, we needed to determine pre VPP utilisation profiles and post VPP utilisation profiles. For batteries, we conceptualised that to harness and maximise the economic benefits associated with the battery, the VPP operator would:

- Primarily seek to maximise its operation into the balancing market, and more specifically, purchase energy during low priced half hour periods, and sell energy during high priced half hour periods.
- Seek to provide other ESS services wherever that is technically and operationally possible (given the half-hour charge / discharge profile that would be required to support its operation into the balancing market).

31 Not modelled, see footnote 19.

32 This is because it will have the same effect on the capacity requirements of the wholesale market customer as defined in the RCM.

33 There are range of regulatory instruments that, in theory, could enable these benefits to be captured by aggregators including prudent discounts, reference services or alternative option contracts. Cost-reflective locational price signals for network access would also allow network users to capture benefits, but these are not currently implemented in WA for most connection points.

In partnership with:
western power synergy AEMO Government of Western Australia Energy Policy WA

For other DER devices, in theory, a VPP could orchestrate each of those devices differently each day, depending on the particular circumstances affecting that day. This was not possible within the computational capabilities that could be included in the model built for this project,[34] and in any case, would have added only minimal information of value to the study. However, to allow for the potential for there to be differences in the utilisation of each device on particular types of days (e.g., air-conditioning on peak demand days), we conceptualised a number of prototypical (or characteristic) days, for which we developed load profiles for each of the devices (except BTM batteries).[35] The prototypical (characteristic) days considered were:

- Peak summer day
- Average summer day
- Average autumn day
- Peak winter day
- Average winter day
- Average spring day
- Minimum demand day(s).

Based on the load profiles developed (the basis for which is discussed in further detail below), and the fact that the information provided by the Project Symphony Partners[36] enabled us to identify how many of these days occurred in each of the forecast years and what the average price by half-hour period would be on those days, we were able to identify the economic benefit resulting from the likely responses of those DER devices on those types of day across each of the benefit categories that are included in the model. Those benefit categories are discussed in more detail in the table below.

Table 2: Overview of how we modelled each type of device for each key economic benefit

Benefit category	Modelling
Balancing market economic benefits	<u>DER devices (except BTM battery)</u> ½ hourly balancing market costs for each prototypical day in each year are averaged. These averaged ½ hourly costs are then applied to the difference in the pre-VPP and post VPP consumption profiles of each DER type and multiplied by the number of occurrences in each year, to determine the incremental wholesale costs to serve each DER type under a pre-VPP and post-VPP scenario. <u>BTM VPP-enabled battery[37]</u> A BTM battery is assumed to be able to be charged daily during the four lowest ½ hourly balancing market cost periods and discharged during the four highest ½ hourly balancing market cost periods, adjusted for a depth of discharge assumption (75%) and a discount of 10% to provide some adjustment for the perfect foresight that is a feature of the model.[38] A daily charge/discharge cycle is assumed.

[34] See Section 3.4 for a discussion of relevant study and model limitations.

ESS economic benefit	<u>DER devices (except BTM battery)</u> Assumed not to be able to provide regulation raise and lower services but can be enabled to a greater or lesser extent for contingency reserve services, noting that these services are of lower value on the basis of modelling input assumptions provided by the Project Symphony Partners. The pre- and post-VPP load profiles of these DER devices are discussed in Section 3.4 below.[39] For contingency lower services, the model assumes that the post VPP load profile for each of the prototypical days for each device provides the basis for how much load is available to be switched on or off during each half hour period, and hence the amount of capacity that can be enabled for contingency services. This load gets multiplied by the average enablement price for the contingency service, derived from information provided by the Project Symphony Partners. For contingency raise services, the model assumes that the quantum that could be enabled for each DER device depends on the following: • If there is no load occurring in a half-hour period, this quantum is assumed to be the maximum load contained in the pre- or post-VPP load profile (on the assumption that this is the load the device could reasonably be assumed to consume at its maximum); or • If there is already load assumed to be occurring in a half-hour period in the post-VPP load profile (i.e., if the VPP provider is already assumed to have moved some of that device's load to that half hour period), the enablement amount is based on the difference between the maximum level of consumption contained in either the pre- or post-VPP load profile, and what is already assumed to be being consumed. In both cases, the model allows specific half-hourly periods to be set to 'unavailable', over-riding the above calculations. <u>BTM VPP-enabled battery</u> The profile of enablement across the ESS services is highlighted in Figure 5, which appears below. The assumptions underlying the profile are that the battery is: • Unlikely to offer to provide ESS services during its key charge/discharge periods (which, as described above, are driven by balancing market prices).[40] • Enabled to provide lower services during periods where it is assumed to have relatively low storage levels (which align to times after it has discharged, but before its charging cycle commences). • Enabled to provide raise services during periods where it is assumed to have relatively higher storage levels (which align to times after it has been charged, but before it has commenced the discharging cycle).

35 This information was not required for BTM batteries due to their ability to be charged and discharged in order to be available for VPP duty without compromising the functioning of the host facility.

36 We were able to identify, from the data provided, which forecast day was expected to be the peak summer and peak winter demand days, and the days on which demand was forecast to be below the threshold defined as minimum operational demand.

37 The estimated economic costs of operating the battery as a 'dumb' (non-orchestrated) battery (i.e., our no-VPP base case) is deducted off this economic benefit as the 'dumb battery' benefit would have occurred anyway. This is calculated in the model based on a PV generation profile (provided by the Project Symphony Partners), a residential consumption profile (provided by the Project Symphony Partners), and algorithms that maximise self-consumption from the battery given the assumed flat tariff. The charge / discharge profiles are overlaid on the scenario-based future market half-hourly projection of balancing costs to estimate the economic benefit of operating the battery in a non-orchestrated manner.

38 The model will always pick the best half hours in which to charge and discharge the battery. The model allows the user to include a discount to reflect that in actual operation the VPP operator is unlikely to choose the best half hours every time.

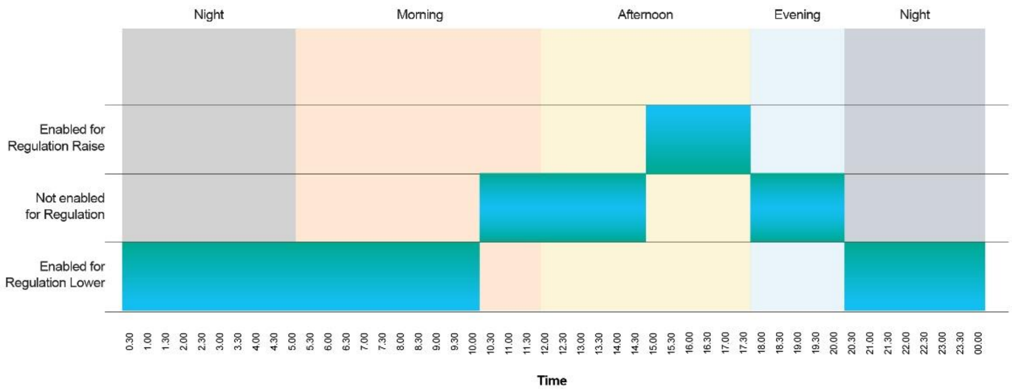
39 See particularly Figures 3 through 6.

40 For modelling purposes, it was assumed that BTM batteries participating in the VPP would charge and discharge at high rates during set periods defined in accordance with the difference in balancing market prices. Accordingly, they could not be available in the modelling for ESS services during those key charge/discharge periods. Charge/discharge timing and rates could potentially be more nuanced in actual operation.

<table>
<tr>
<td></td>
<td>We have run two modelled cases – one where the battery provides regulation raise and lower services, and one where it is assumed to only be able to provide contingency regulation raise and lower services. In is worth noting that the battery enablement profile in Figure 5 remains constant for all services in this modelling.

It is assumed that non-orchestrated batteries do not directly provide ESS services, hence all ESS benefits are assumed to be incremental to the base case.

Figure 5: Battery enablement daily profile



Source: OGW estimate</td>
</tr>
<tr>
<td>Network support benefits (both for peak and minimum demand):</td>
<td><u>DER devices</u>

The model allows the user to nominate the time interval and season when peak demand will occur (NB: this allows the timing of peak demand to change across the years in the model). The difference in the defined peak season's load profile (e.g., either summer or winter) and that in the no-VPP base case, during the time intervals nominated by the user, is the basis for the quantum change in peak demand from that device.

For the purposes of our modelling, we have assumed that peak demand will continue to occur in summer over the forecast time horizon, and that it will occur between 4.30 pm and 7 pm, and hence it is the average load reduction over the time period that gets multiplied by an estimated long run marginal cost (LRMC) associated with peak demand, expressed in $/kilovolt amp (kVA).

<u>BTM VPP-enabled battery</u>
For peak demand support, this is based on the kilowatt (kW) capacity of the battery and the time over which the network support is available, discounted for depth of discharge limits and an allowance for perfect foresight, multiplied by an estimated LRMC associated with peak demand.

For support during minimum demand periods, it is based on the kilowatt hour (kWh) size of the battery and the value ascribed to the consumption of energy during these minimum demand periods.</td>
</tr>
<tr>
<td>RCM (supply-side) / IRCR (demand-side) economic benefits</td>
<td><u>DER devices</u>

No allowance is made for participation in the RCM. IRCR support is based on the same approach as network support (for peak demand), except the quantum reduction during the defined peak is multiplied by the forecast reserve capacity price (RCP) in the forecast year.

<u>BTM VPP-enabled battery</u>

The value of capacity credits allocated to a battery is based on the output the battery can sustain over four consecutive hours, multiplied by the forecast RCP in each forecast year.</td>
</tr>
</table>

The source of these input assumptions is outlined in Section 3.4 below.

3.3.2.3 Combining VPP costs and benefits to estimate VPP take-up

All the above analysis of economic benefits is undertaken at a device level; to convert this to an overall economic benefit (cost), we had to:

- Incorporate the economic costs associated with setting up and operating the VPP; and
- Aggregate both the economic benefits and economic costs across the expected size of the VPP (i.e., the number of each type of DER devices being orchestrated in each year).

In relation to the former, the quantified incremental economic costs are contained in the table below.

Table 3: Overview of economic costs included in the model

Cost category	Description of costs
Upfront program set up costs	Upfront costs of setting up the VPP (i.e., platform, hardware and set-up costs)
Program fixed annual costs	Annual fixed costs of running the VPP (e.g., platform maintenance)
Capital and annual operating cost per DER device enabled	• Capital costs to connect end-use devices to the VPP (i.e., the cost of the communications and management technologies as their installation), including any changes forecast over the study timeframe in these costs • Annual cost of operating customers' end-use devices in the VPP (i.e., license fees and communication costs)

The source of these input assumptions is outlined in Section 3.4 below.

We estimated the financial benefits and direct costs[41] to residential customers of allowing each of the five end-use appliances (BTM batteries, electric storage water heaters, pool pumps, direct load control of reverse cycle air conditioners, and EVs) to be orchestrated by the VPP. The financial metric that is calculated is returned as a percentage of upfront cost. This figure, combined with the estimated relationship between this financial metric and historical PV take up, discounted for a range of specific features affecting VPP-enabled batteries and other devices as compared to PV-only

[41] For the purposes of this analysis, we assumed that the incremental cost of any specific equipment required to enable a specific device to be orchestrated would be charged up front to the customer. We also assumed that the customer would consider an estimate of the financial impact that enabling their device might have on their electricity retail bill. So, for example, the with-VPP case implicitly assumes that the VPP operator will be able to discharge a customer's battery extensively in the later evening (as this is when balancing prices are generally at their highest). The opportunity cost to the customer is that they are foregoing the ability to utilise that energy to displace grid consumed energy later in the evening and through the night. This opportunity cost, being the relevant retail price less the assumed FIT tariffs that would be applied to that exported energy under Synergy's DEBs tariff, is assumed to be included in the customer's financial analysis.

systems,[42] is used to estimate how many of the batteries that are installed under the no-VPP base case, will enter into a VPP arrangement.

The same approach has been adopted for all DER devices, however the maximum take up of these other devices is - for the purposes of the results presented in this report - capped at the take-up of VPP-enabled batteries. This assumption reflects the fact that the results (as discussed in Section 4 below) indicate that the battery is the cornerstone device; that is, the battery contributes significantly more economic benefit per device. Hence for a VPP to be economic, the customer must have a VPP-enabled battery (no matter how many of the other DER devices might be present). This is also discussed in more detail in the section on results.

For completeness, it is noted that the take-up of end-use appliances is not linked to financial payback. However, their participation in the VPP is linked to the incremental costs and benefits of that participation.

3.4 Key Inputs and Assumptions

3.4.1 Pre- and post- VPP load profiles of other (non-battery) DER devices

Figure 6 through Figure 9 below provide information on how the pre- and post-VPP load profiles were developed for each of the DER devices (other than BTM batteries) given that no SWIS specific load profiles were available for these end uses.[43]

- For residential reverse-cycle air conditioners (Figure 6), electric storage water heaters (Figure 7), and pool pumps (Figure 8), publicly available load profile information from manufacturers, published studies and AEMO were used.
- For EVs (Figure 9), load profiles and costing data from AEMO (and Commonwealth Scientific and Industrial Research Organisation) were used.

In all cases, the post-VPP profiles were developed to maximise the consumption of these devices during the solar trough hours.

---

42 We have applied a 5% discount to the relationship between payback and PV uptake to reflect the fact that customers are to be at least somewhat reticent (even where they can expect to benefit financially) to cede management of their battery to a third party (see Section 3.3.2 above).

43 The assumed operation of BTM batteries by the VPP to provide each of the DER services is discussed in Table 2.

Figure 6: Air-conditioning load profiles

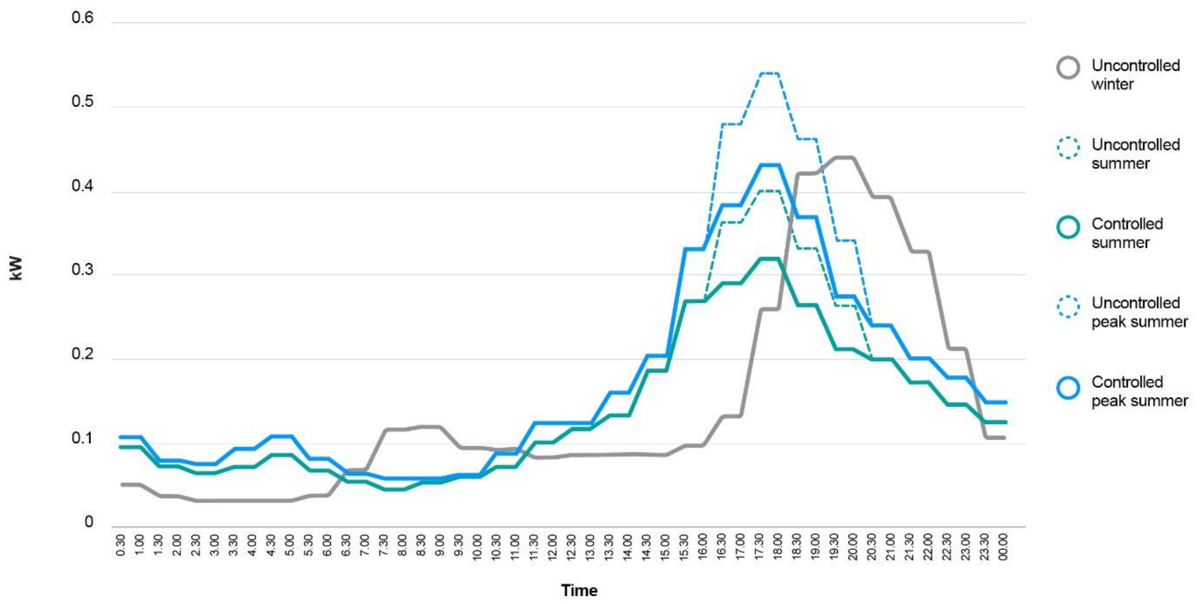


Figure 7: Hot water service load profiles

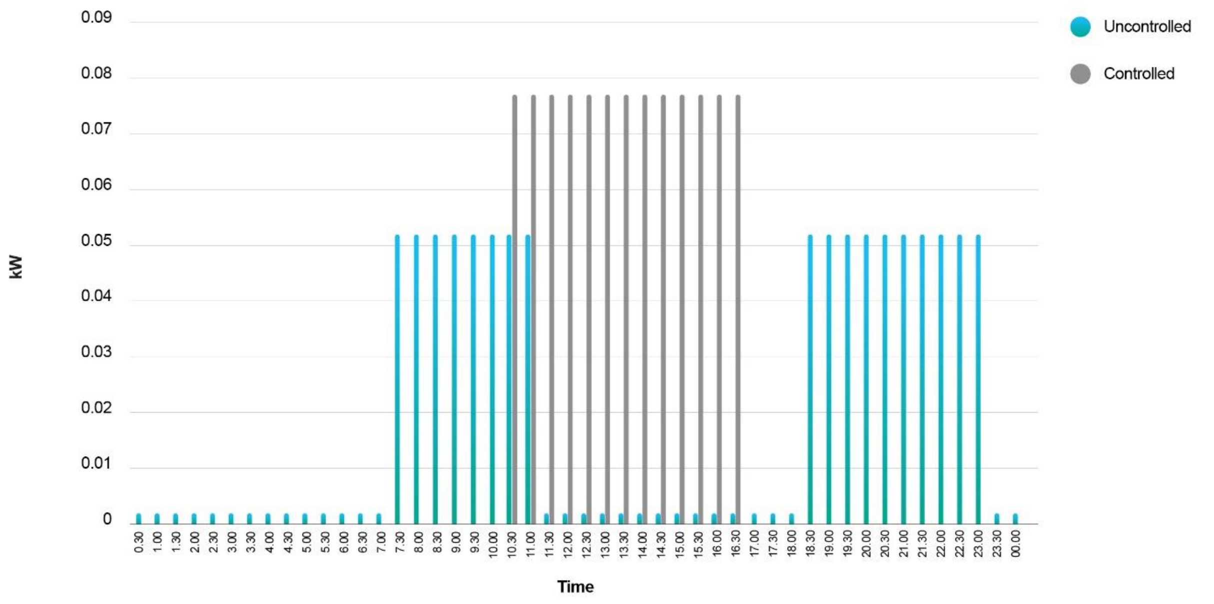


Figure 8: Pool pump load profiles

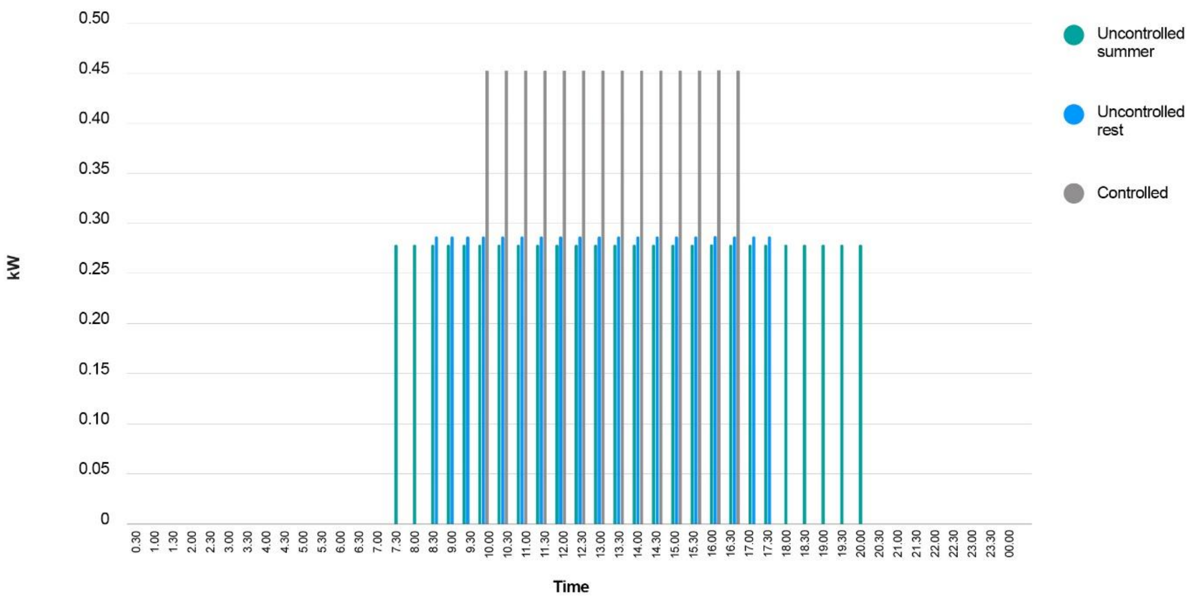


Figure 9: Changes in average EV load profile due to orchestration

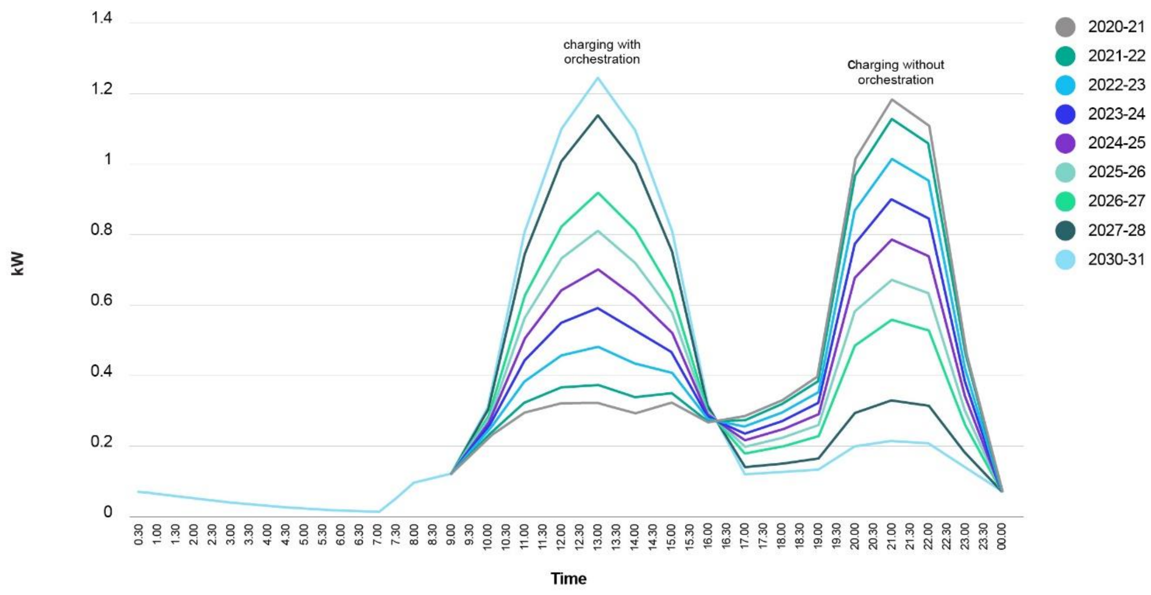


Figure 9 shows the change, on an annual basis, of the charging profile of EVs. The non-orchestrated profile (the grey line) is based on AEMO data that was used as an input into its 2020 Electricity Statement of Opportunities for the WEM. This shows that the bulk of the charging load is expected to occur during the evening with some during the day. The orchestrated version, which is shown in each of the other lines with the shift of load growing as the number of orchestrated EVs increases, shows increased use of day charging and reduced night charging. For the model, we assumed a fast adoption of daytime charging so that the bulk of the charging has moved from night-time charging in 2020-21 (the grey line) to daytime charging from 2025-26 onwards.

3.4.2 Other key inputs and assumptions

Other key inputs and assumptions used in the modelling are discussed in Table 4 below.

Table 4: Inputs and assumptions used in the modelling and their sources

Input / Assumption	Source / Comment
Operating costs for energy dispatched (i.e., balancing market prices)	The Project Symphony Partners provided a scenario-based projection of half-hourly costs and marginal generator information out to 2038. This projection was based on a future market scenario and formed the basis of the costs used, with assumptions made to estimate negative prices.[44]
Marginal costs for ESS provisioned	For each of the four ESS services[45] a scenario-based projection was provided for the purposes of this report of the costs and capacity enabled in megawatts (MW) for each half hour period to 2038. From that, a weighted average per-MW value is calculated for each half hour period, for each ESS service. An average marginal cost (and the number of occurrences) is calculated for each ESS service, by: (a) half-hour period; (b) for each of the prototypical days; (c) for each year, where cost is above a certain threshold (which can be set in the model by the user).[46] The average marginal cost for each ESS is multiplied by the number of occurrences to determine the revenue in dollars per megawatt hour (MWh) that would be available if the DER device was always able to provide that ESS service in that half hour, on that prototypical day, in that year. This is done because the model allows the user to schedule each DER device for enablement for each half-hour period.[47]
Network avoidable costs (Western Power)	Augmentation: $140/kVA based on Energex's published LRMC, noting that Western Power informed us that this was the most comparable network that had published an LRMC. Over-voltage issues (caused by rooftop PV): ranging from between $1/MWh to $6/MWh for the incremental energy consumed by devices during minimum demand days, with this dependent on the wholesale prices in the year. This is based on the value of the energy that would have otherwise been curtailed had the additional load not been there on those minimum demand days. EV: total cost impact of different EV penetrations charging during peak demand periods used to determine an annualised cost per EV (data provided by Western Power).

[44] The scenario-based projection of half-hourly costs and marginal generator information was prepared only for scenario-based projection testing for the purposes of this report. The projection was based on a future market scenario and does not represent or approach a best estimate relied on for short run marginal cost pricing.

[45] Regulation raise and lower; Contingency raise and lower.

[46] The threshold is selected in reference to the retail tariff price of electricity because this is the opportunity cost to the customer of using electricity from the battery for some purpose other than reducing their own use of electricity from the grid. In short, it would not be financially wise for customers to allow energy from their batteries to be used in an application that returns a value that is lower than their retail tariff.

[47] Note that in the modelling, DER cannot be enabled during the key charge/discharge hours, and in actual operation, enablement is subject to appropriate management of the battery's state of charge, via forecasting and re-submissions into the market.

Input / Assumption	Source / Comment
Program costs	Developed in consultation with Project Symphony Partners based on the budget for the Project Symphony VPP. The estimated cost reductions were incorporated into the model.
Non-orchestrated battery charge/discharge profile	Calculated within the model based on: • A PV generation profile (provided by Synergy) • A residential consumption profile (provided by Synergy) • An algorithm that calculates the expected export from the combination of the two profiles above for a residential property with a typical underlying demand and a 'typical' PV and battery system comprised of a 5 kW PV system and a 5 kW/10 kWh battery
Retail electricity price	As noted earlier, the retail price defines the opportunity cost to the customer of allowing the VPP to export electricity that would otherwise be used by the customer and therefore reduce the customer's use of electricity from the grid and therefore the customer's bill. The current analysis uses: • Synergy's current A1 residential tariff; and • The Renewable Energy Buyback Scheme (REBS) and Distributed Energy Buyback Scheme (DEBS) export tariffs (buyback rate). The model includes the ability to assess VPP outcomes under either of two alternative tariff structures: a static time-of-use tariff or a demand tariff.
PV take-up	A PV take-up forecast provided by the Project Symphony Partners was used in developing the market price projections used in the analysis.
Battery take-up	The battery take-up forecast was provided by the Project Symphony Partners, based on the AEMO's WEM 2021 Electricity Statement of Opportunities.

3.5 Caveats and limitations

It is important to note that the study approach, the model used and the data that was available to the study all have limitations. These should be recognised in considering and interpreting the results. Limitations and caveats include the following:

- The analysis has been undertaken based on a future market scenario projection that has been made at a specific point in time. While the values for each of the specific items being projected (e.g., balancing market prices, essential system services prices, etc), change over the years within the projection horizon, the projections themselves have not been revised to reflect the level of the services and the new demands that would be expected to result from the operation of the VPP as it grows over time. In reality, the actions of the VPP could potentially change those prices, which would then affect the future development of the VPP itself. Capturing these sorts of dynamic interactions is complex and the use of simplifying assumptions such as the use of a single, initial projection is very common.

- Similarly, the model assumes current tariff structures will continue into the future as part of the base case, no-VPP assumption.[48]
- The methodology used to forecast take-up of the VPP arrangement is informed by the payback acceptance levels revealed in the take-up of rooftop PV systems. However, participation in the VPP – that is, how much control the participating customers will be prepared to allow the VPP to exercise over their battery storage systems – is a different matter. We have assumed the battery is able to be exercised by the VPP every day of the year, and while the level of exercise assumed preserves a margin of the battery that is always available for use by the participating customer,[49] actual operational results when the VPP is implemented may vary from these assumptions.
- The study (and the modelling) focuses only on residential customers for VPP participation. It did not include consideration of contributions that could be provided by end uses or generation sources located in commercial or industrial facilities. Similarly, the study did not consider the VPP owning and/or operating direct network connected batteries despite the potential of such assets to contribute to a VPP's asset structure. As a consequence, the results of the study, in terms of the reported economic net benefits from DER orchestration, are likely to be conservative.
- This study used average seasonal days and prices, an average customer with average electricity consumption and consumption profile, an average-sized PV system and an average-sized BTM battery. In actual practice, different types of customers may find VPP arrangements more and less attractive, which may make a difference to actual take-up and benefit realisation. It could also influence the size of PV and battery systems that are taken up which could also affect the level of benefits realised.
- A further complication to the use of averages was the fact that the total population assumed to be eligible to participate in the VPP was defined as the number of customers forecast by AEMO to install BTM batteries over the study timeframe. It was assumed that those customers could also have the other DER devices that could be orchestrated by a VPP (reverse cycle air conditioning, electric storage water heating and pool pumps). It was also assumed that the availability of the benefits that a customer can derive from enrolling in a VPP would not result in more batteries being installed than the number forecast by the Project Symphony Partners.
- The modelling was undertaken at the SWIS level. This imposed a limitation on the degree to which the model could focus on the benefits that the VPP can provide to the distribution network. Network operating issues and augmentation requirements are all driven by local conditions: the nature of these problems and the solutions to them vary widely from location to location. The SWIS level of analysis precluded the use of locational network cost data for the study.

48 Changes in residential electricity tariff structures and levels (and/or export buyback tariffs) would change the financial attractiveness of the VPP offer as compared to the continued use of an un-orchestrated battery, and therefore take-up. The modelling was undertaken in constant 2021 dollars.

49 This was based on information from the actual practice of several VPP operators.

- While VPP management and dispatch of rooftop PV systems that are not coupled with a BTM battery is technically possible and potentially valuable, this configuration was not included in the modelling undertaken for this report, as explained below.

  One of the primary focuses of the VPP as modelled was its ability to move load into the middle of the day, either through the discharge of the BTM battery or by shifting the time at which the other DER devices are energised. Any such load additions in the middle of the day, all things being equal will serve to reduce the amount that PV export from rooftop systems that are not paired with BTM battery would need to be curtailed.

  In any case, there are measures planned in WA, as discussed in Section 3.2, that will provide the ability to curtail the export of PV that is not paired with a battery or not participating in a VPP in those instances where that curtailment is needed to protect the stability of the generation/transmission system or to manage reliability and voltage levels in the distribution network.

  The deployment of those measures in combination with the VPP, will provide a suite of measures that will enable customer market participation, support further PV growth and reduce the need for last resort measures while providing a backstop to ensure power system security and stability. It may also allow the system to accommodate increased DER capacity and DER generation. To the extent that this potential is realised the analysis presented in this report is likely to be conservative with regard to the total capability that may ultimately be available through the establishment of a VPP.

4 Model Results

4.1 The 'no-VPP' base case

For the purposes of the modelling, we assumed that, in the absence of the VPP being established (i.e., the 'no-VPP base case'):

- The number of BTM batteries forecast to be installed over the modelling horizon will in fact be installed and none of them would participate in a VPP arrangement (i.e., none would be able to be dispatched in response to price signals from the electricity supply chain)[50]
- The number of EVs taken up and how they are charged would be as forecast by AEMO[51]
- The number of each of the other (non-BTM battery) DER devices in existence is as provided by Synergy and none of them are currently or are forecast (in the absence of the VPP) to be managed or enabled for remote dispatch.

It should also be noted that at the time the modelling was undertaken, the government was consulting on a requirement whereby rooftop PV systems could be constrained off at times when operational demand falls below the minimum required for system stability. However, the exact nature of the arrangement to be put in place was not known, and an assumption had to be made. That assumption was that from 2023-24 all rooftop PV systems (both existing and new) would be capable of being constrained off when needed.[52]

This means that the modelling will have assumed the ability to constrain off more PV export than will actually be provided by the government's arrangement. This will result in the value of ESS used in the modelling being lower than it would have been had the nature of the government arrangement been known prior to the market simulation having been undertaken, thereby tending to make the results of the modelling conservative.

---

[50] The data used in the base case reflects the assumptions that the Project Symphony Partners considered were most likely to occur in the absence of DER orchestration. It should be noted that those forecasts and assumptions may have changed since that time.

[51] AEMO 2020 Inputs and assumptions for SOO.

[52] As subsequently decided and published by government, the arrangement will affect only those PV systems installed from December 2021 on.

4.2 Model results by scenario

4.2.1 Overview of scenarios and scenario results

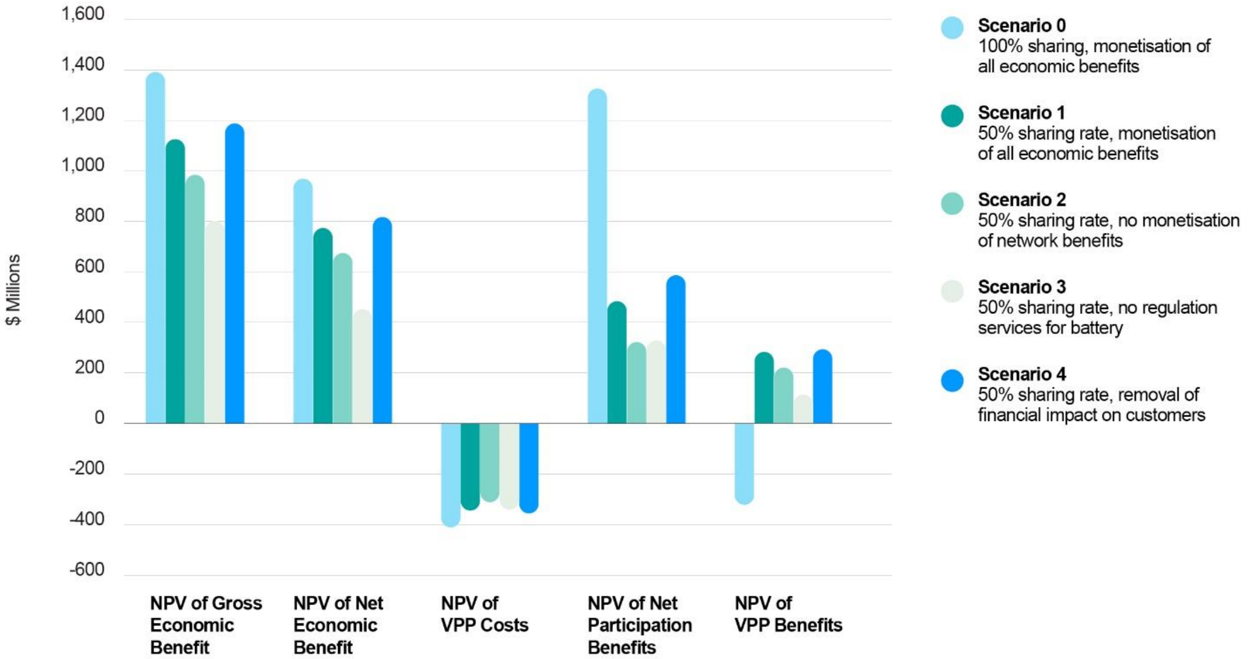
Table 5 below summarises the scenarios that have been modelled:

Table 5: Scenarios modelled

Scenario Name	Description
Scenario 0 - 100% sharing, monetisation of all economic benefits	This scenario assumes that all economic benefits flow through to VPP customers (i.e., there is no sharing of economic benefits) and all economic benefits can be monetised. This leads to the maximum number of customers taking up the VPP.
Scenario 1 - 50% sharing rate, monetisation of all economic benefits	This scenario assumes that all economic benefits can be monetised, and those economic benefits are shared equally between the VPP provider and its customers. As compared to Scenario 0, this leads to a lower take up by customers, but it presents a more commercially attractive proposition for a VPP provider.
Scenario 2 - 50% sharing rate, no monetisation of network benefits	As above, except that it is assumed that due to the absence of cost-reflective price signals and/or regulatory instruments that can effectively facilitate non-network solutions, the VPP provider is unable to monetise the economic benefits that its orchestration of VPP devices provides to Western Power.
Scenario 3 - 50% sharing rate, no regulation services for battery	This scenario assumes that all economic benefits that can be monetised are shared equally between the VPP provider and its customers. However, it assumes that BTM batteries are unable to provide regulation services (and instead, provide contingency raise and lower services – based on the enablement profile provided in the previous section; regulation services are provided in all other scenarios)
Scenario 4 - Removal of financial impact on battery customers	This scenario assumes that all economic benefits can be monetised, and those economic benefits are shared equally (50/50) between the VPP provider and its customers. However, this scenario removes the financial cost that VPP customers would face if they allowed the VPP operator to discharge their battery during high priced balancing market periods, depriving them of the energy in their battery to offset their own consumption preceding the discharge event.

Figure 10 below summarises the results of the scenarios.

Figure 10: Summary of results



Source: OGW analysis

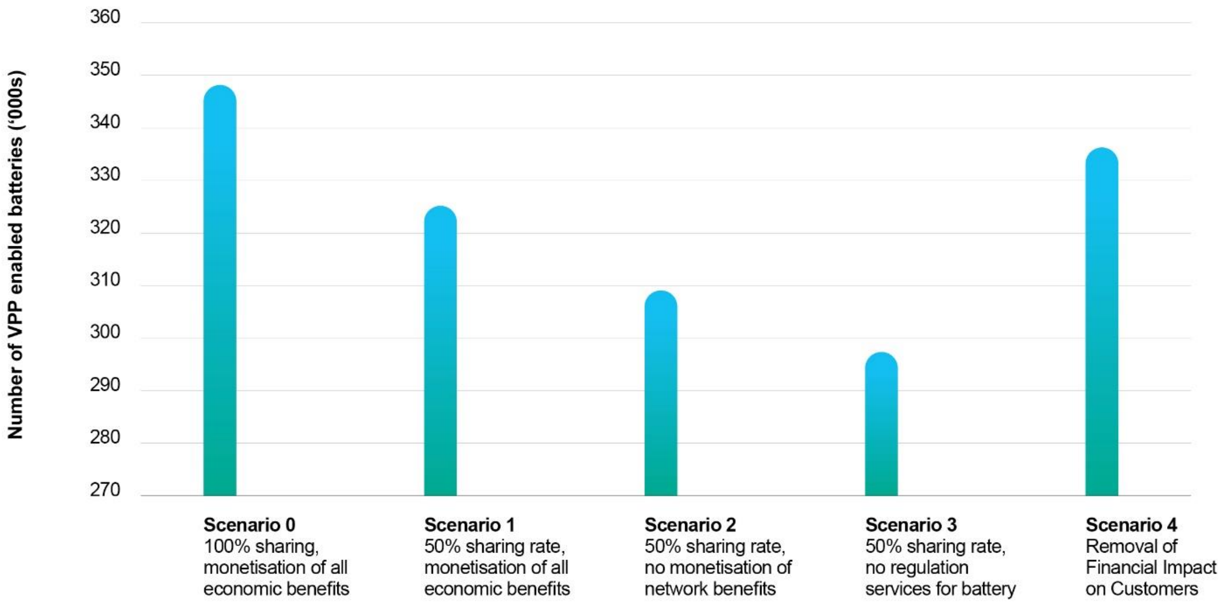
In relation to Figure 10:

- The ‘Gross Economic Benefit’ reflects the total economic benefit calculated under each scenario in NPV terms, excluding any economic cost associated with implementing the VPP
- The ‘Net Economic Benefit’ reflects the gross economic benefits less the estimated economic costs of implementing the VPP, expressed here in NPV terms
- The ‘VPP costs’ reflects the cost of implementing the VPP in NPV terms
- The ‘Net Participant Benefit’ is the *net* benefit that accrues to participants (being the providers of the DER devices which are orchestrated via the VPP) under each of the scenarios, which reflects: (a) the proportion of the economic benefit that is assumed to be passed on to them under that scenario (e.g., the sharing ratio); (b) the upfront costs they are assumed to have to incur in order to participate in the VPP; and (c) except for Scenario 4, the financial opportunity) cost they face from allowing their devices to be managed the VPP operator
- The ‘VPP benefits’ reflect the benefit to the VPP provider, in NPV terms, taking into account: (a) the proportion of the economic benefit that they are assumed to retain under each scenario (e.g., the sharing ratio); and (b) the cost of implementing the VPP.

4.2.2 Battery take-up

Figure 11 below demonstrates the VPP battery take-up under each of the scenarios.

Figure 11: VPP battery take up by scenario

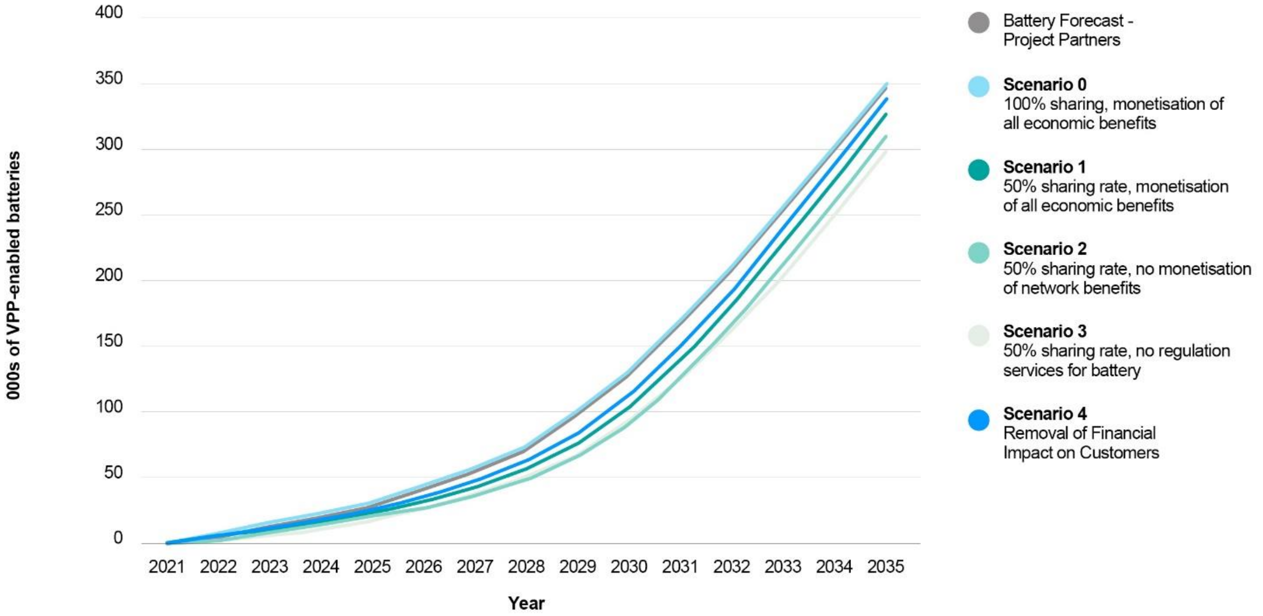


Source: OGW analysis

For context, Figure 12 below shows the forecast take-up of batteries over time. As can be seen, the underlying forecast of battery take up is highly skewed towards the last five years of the evaluation period,[53] which in turn flows through to the assumed take-up of batteries under the VPP due to assumed reductions in battery purchase costs.

[53] More than two thirds of the take-up occurs in the last six years of the 15-year forecast period.

Figure 12: VPP battery take up over time



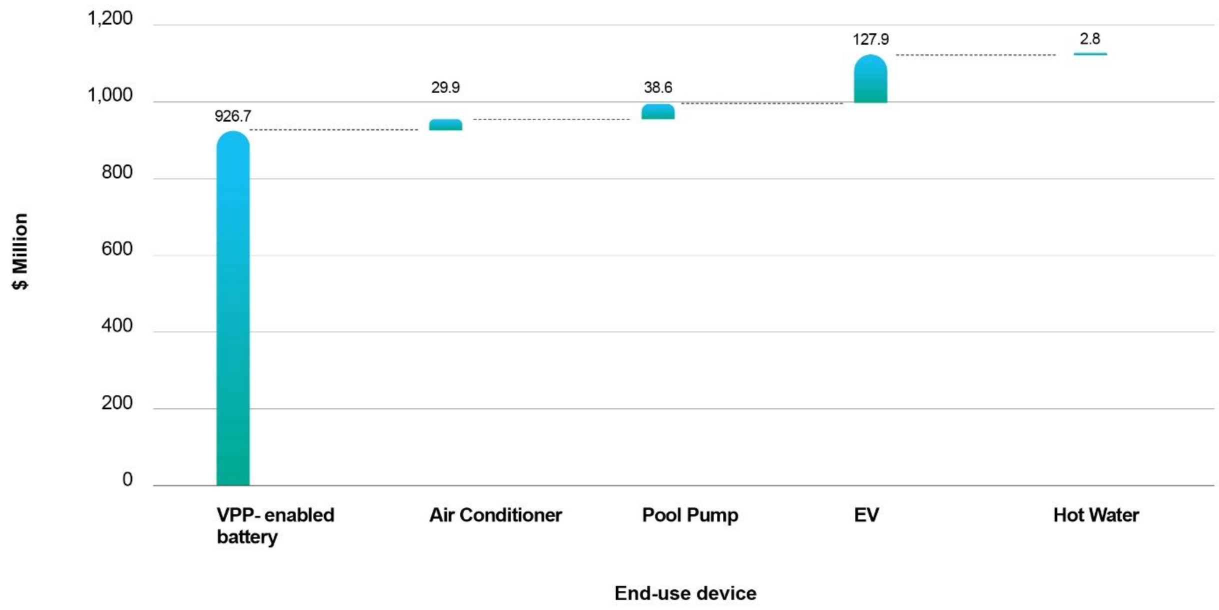
Source: OGW analysis

4.2.3 Contribution of the various DER devices to overall economic benefit

Figure 13 and Figure 14 demonstrate the contribution each DER device category makes to economic benefits under both Scenario 1 and Scenario 3, which assumes batteries cannot provide regulation raise and lower services.

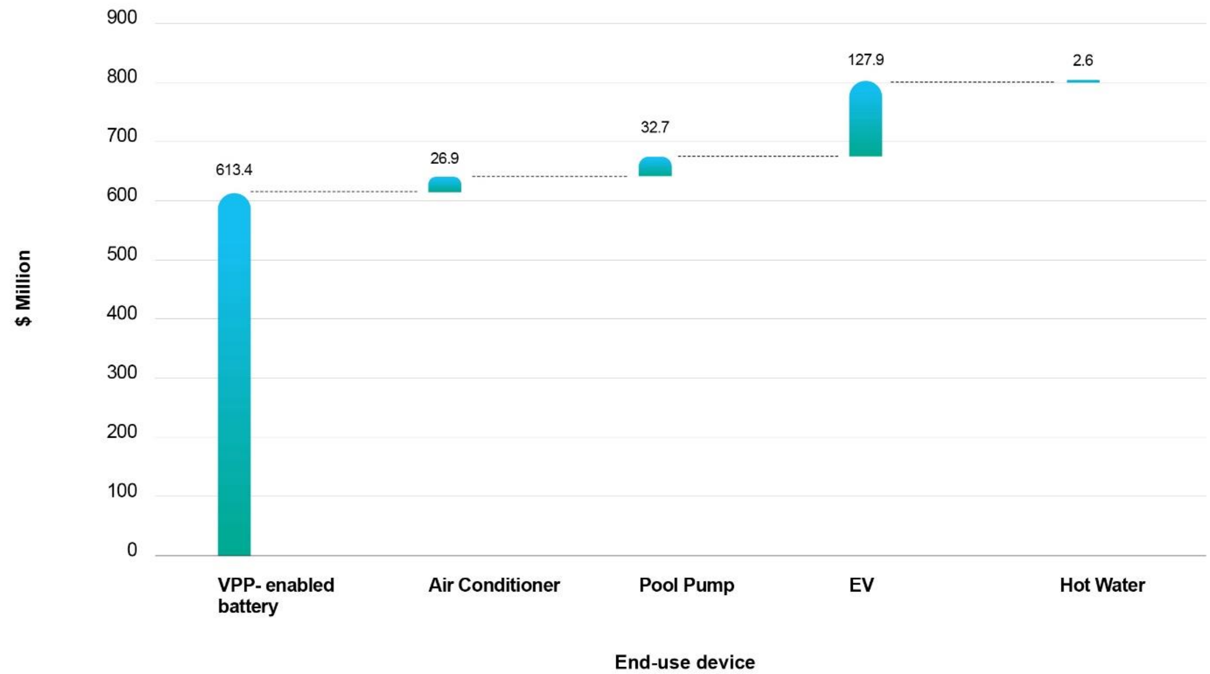
As can be seen by comparing the results shown in Figure 13 with those in Figure 14, the availability of revenue from regulation ESS (particularly the regulation lower service at current forecast prices) makes a very significant difference to the gross economic benefit that can be delivered by a VPP. The magnitude of the difference is a result of the annual revenue available per participating customer, and the number of participating customers, which increases as the financial value of participation increases to customers with BTM batteries.

Figure 13: Contribution to gross economic benefits (Scenario 1)



Source: OGW analysis

Figure 14: Contribution to gross economic benefit (Scenario 3 - no regulation services)



Source: OGW analysis

4.2.4 Summary and discussion of outcomes

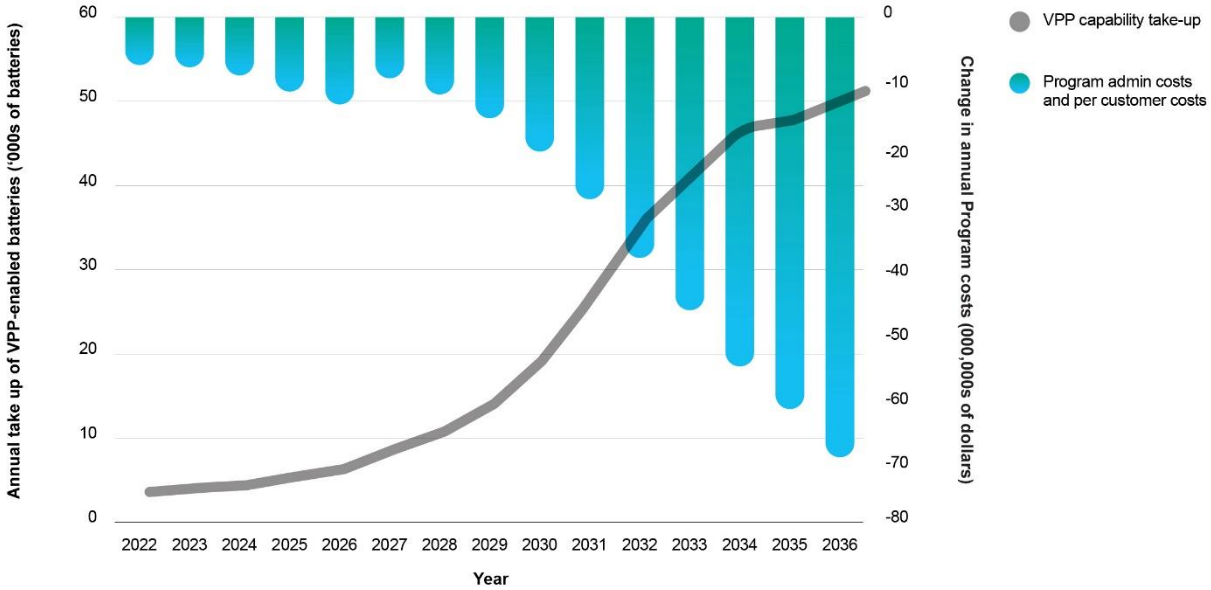
In summary:

- All scenarios produce positive gross economic benefits. The maximum gross economic benefit is produced in Scenario 0 at just over $1.4bn in present value terms,[54] based on a weighted cost of capital (WACC) of 4%.
- The gross economic benefits decline as we work through Scenarios 1 through 3. This is due to:
    - Scenario 1: Lower customer participation in the VPP due to the application of a lower sharing rate
    - Scenario 2: Lower customer participation in the VPP due to the application of a lower sharing rate and the inability to monetise one of the economic benefits (the network related benefits)
    - Scenario 3: Lower customer participation in the VPP due to lower sharing rate and lower gross economic benefits due to the assumption that batteries are unable to provide regulation raise and lower services.
- In Scenario 4 gross economic benefits increase most of the way back to the level of Scenario 0. This is the result of the removal of a significant source of opportunity cost to the customer, which has the result of increasing take-up.
- The maximum net economic benefit of $967m over the 15-year forecast time horizon occurs in Scenario 0, but falls to just over $776m and $671m under Scenarios 1 and 2, and to $453m for Scenario 3.

Figure 15 below shows the relationship between annual program costs and annual battery take up. Program costs include establishment and set-up costs and all VPP operating costs (which increase as the total number of batteries in the VPP increases). The reduction in costs in year 6 reflects the expected reduction (of about 45%) in the costs of the technology used by the VPP to communicate with the DER devices that join the VPP from that year.

[54] It should be noted that this is a statement of economic value and should not be misconstrued as the amount of benefit that customers (whether participating in the VPP or not) would experience in their bills. Actual monetary impact to participating customers will depend on a host of factors including (but not limited to) whether the economic values considered in the study are actually reflected in price signals available to the VPP, how the level of those price signals change over time, whether and how retail tariffs change, how the VPP shares benefits with participating customers, and the nature of relevant regulatory mechanisms such as whether and to what extent network benefits are shared between the network operator and the VPP (as the entity providing those benefits).

Figure 15: Annual program costs compared with annual take up



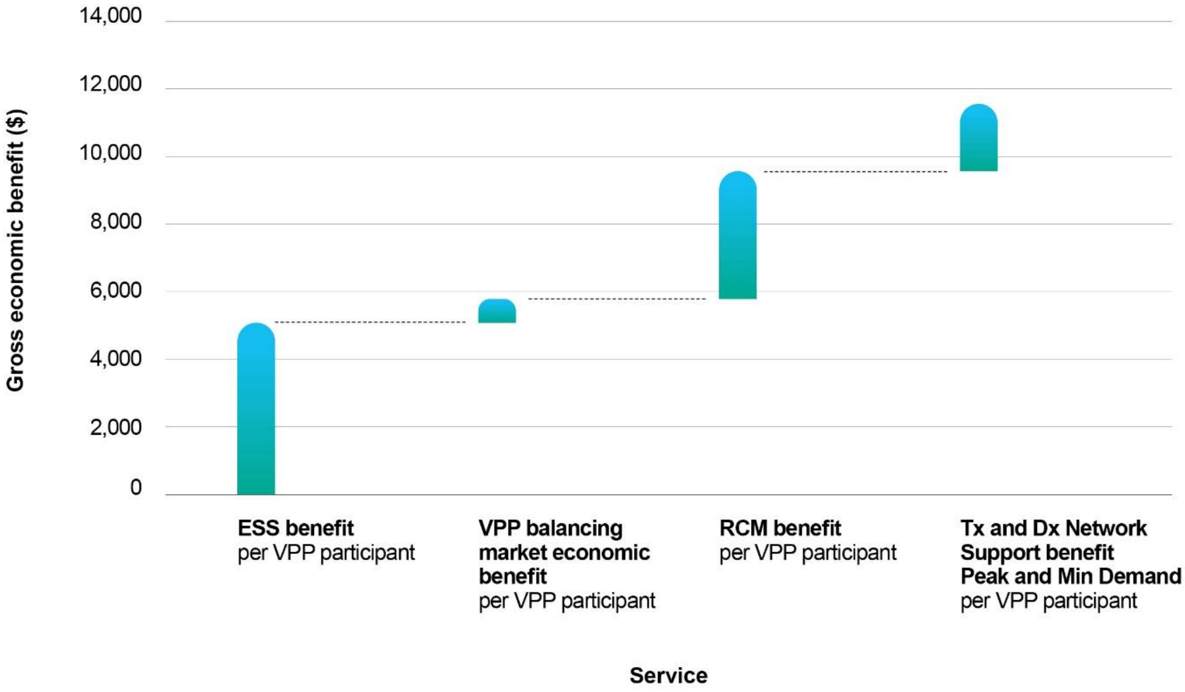
Source: OGW analysis

As shown in Figure 13 and Figure 14, it is the BTM battery that contributes the majority of gross economic benefits, unless if it is unable to provide regulation services.[55] Therefore, in terms of targeting customers, the BTM battery effectively becomes the gateway to enabling the potential economic operation of a VPP within a customer's property, or put another way, absent a battery there is little benefit in targeting a customer for inclusion in the VPP. This is further illustrated by assessing the average economic benefit (i.e., the total economic benefit regardless of the proportion shared by the VPP with the customer) provided by each of the devices (see Figure 18 below).

As alluded to above, ESS services, and regulation services in particular, are the primary contributor to the economic benefits that are generated from a VPP-enabled battery. This can also be seen by comparing the gross economic benefit provided by a VPP battery in the case where it can provide regulation service (Figure 16) with the case in which it cannot do so (Figure 17).

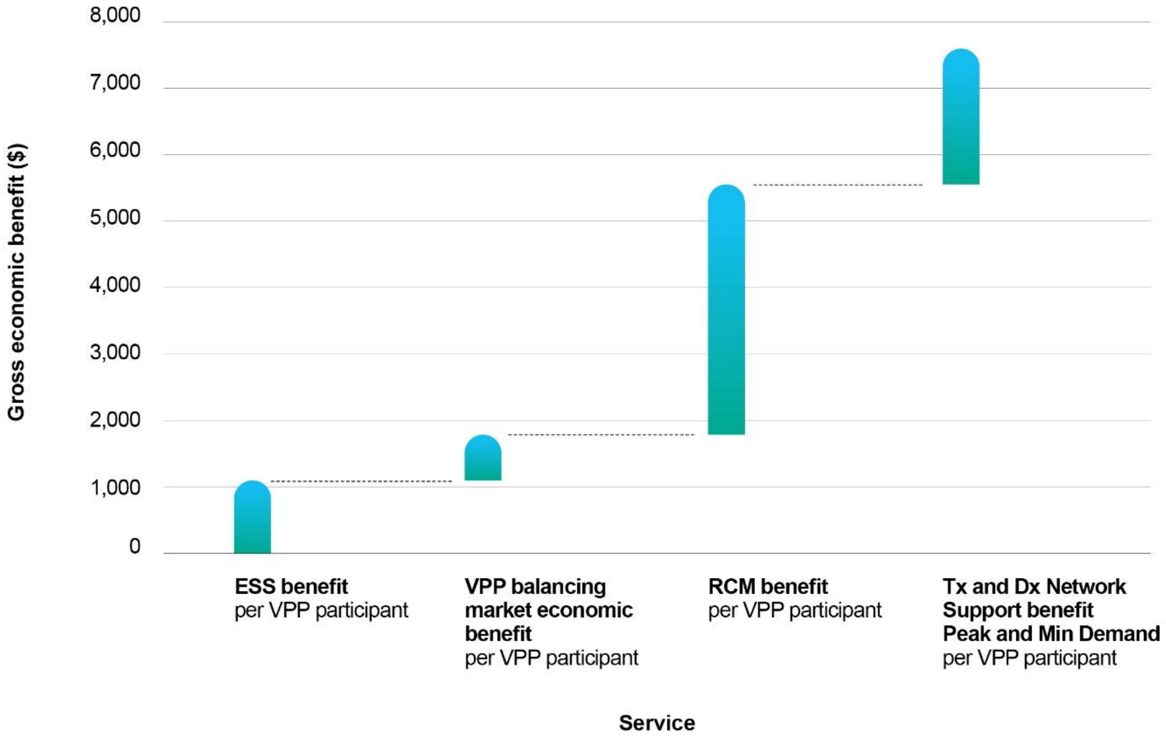
55 If the battery cannot provide regulation services (or the VPP decides not to pursue that value stream) it is assumed that the VPP pursues contingency ancillary services – the only difference is the value that can be derived, which affects take-up and therefore total benefit realisation.

Figure 16: Contribution to a VPP battery's gross economic benefits (with regulation services, Scenario 1, NPV, 15 years)



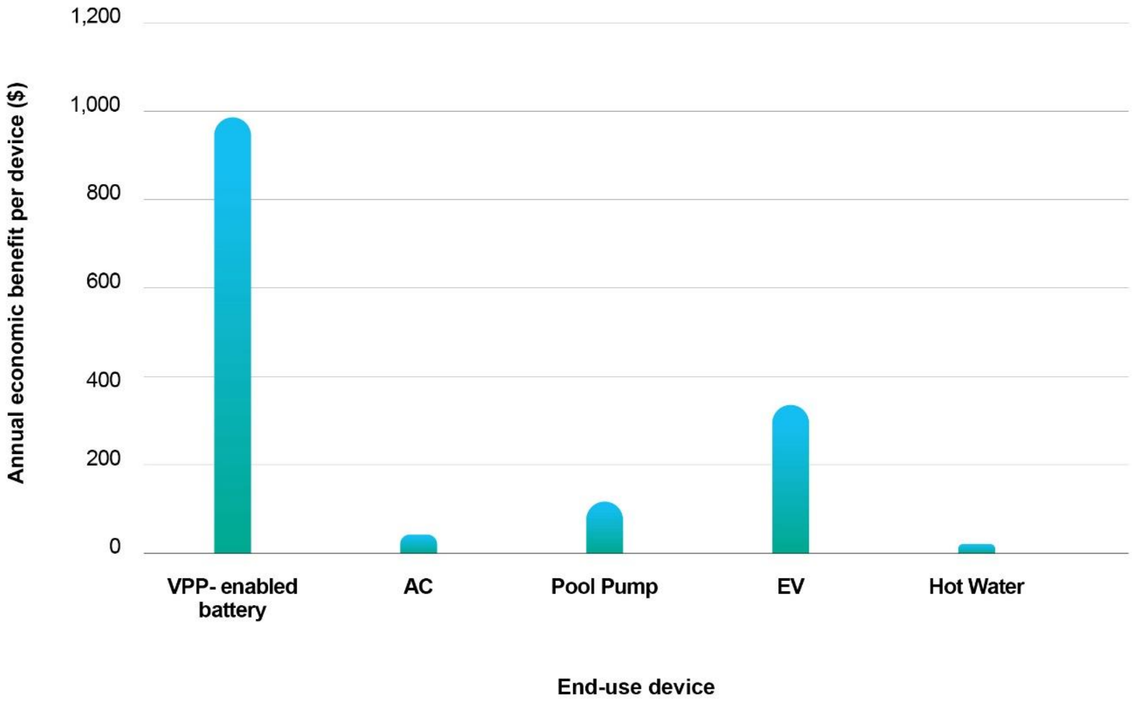
Source: OGW analysis

Figure 17: Contribution to a VPP battery's gross economic benefits (no regulation services, Scenario 3)



Source: OGW analysis

Figure 18: Average annual economic benefit per device



Source: OGW analysis, all scenarios except Scenario 3

Comparing Figure 16 with Figure 17 shows that the ability to provide regulation ESS, at currently forecast prices, increases the annual revenue available on a per customer basis by around 50%.

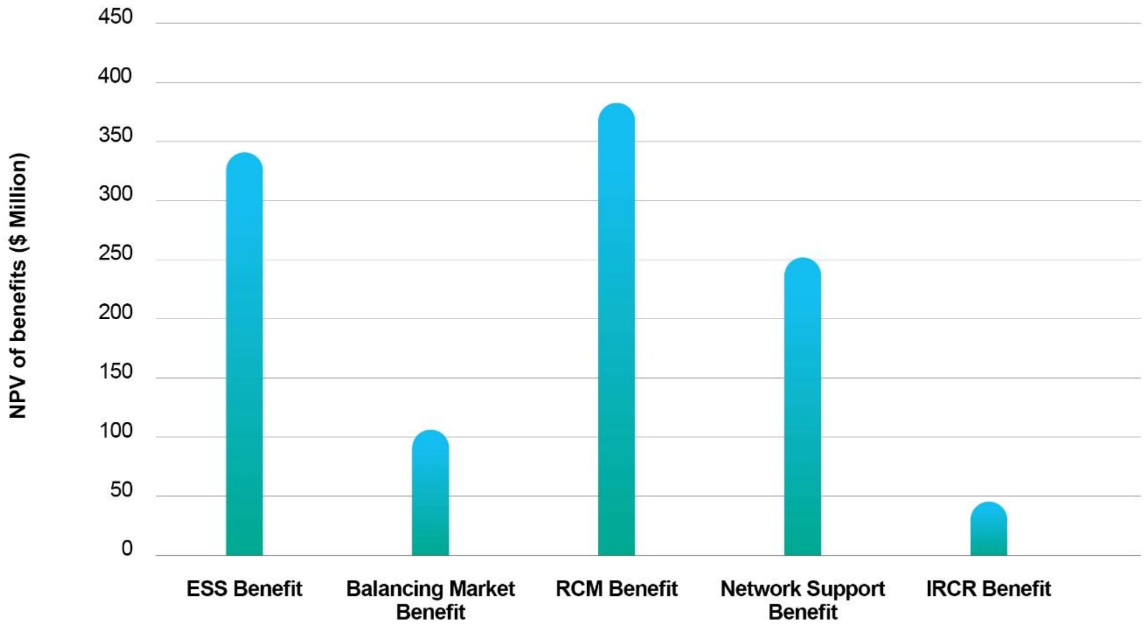
Figure 19 below shows the overall contribution each of the services makes over the 15-year operating life of the VPP, assuming the BTM batteries can provide regulation services.

As shown by comparing Figure 19 with Figure 20, however, if VPP-enabled batteries are unable to provide regulation services, the relative contribution ESS services make to the total economic benefit of the VPP declines materially. The declines in the overall economic benefits accruing to other services results from the lower take-up under Scenario 3, which occurs because of the lower financial return available to the individual DER provider.

Finally, it is worth noting that the VPP could result in a significant source of new dispatchable generation in the WEM. As shown in Figure 21 below, based on the economic benefits available, the VPP could result in the addition of over 1,600 MW of dispatchable generation. For context, it should be noted that peak demand within the National Electricity Market (NEM) at present is about 4,000 MW and Collie, the largest central generation plant in the WEM is about 340 MW.[56]

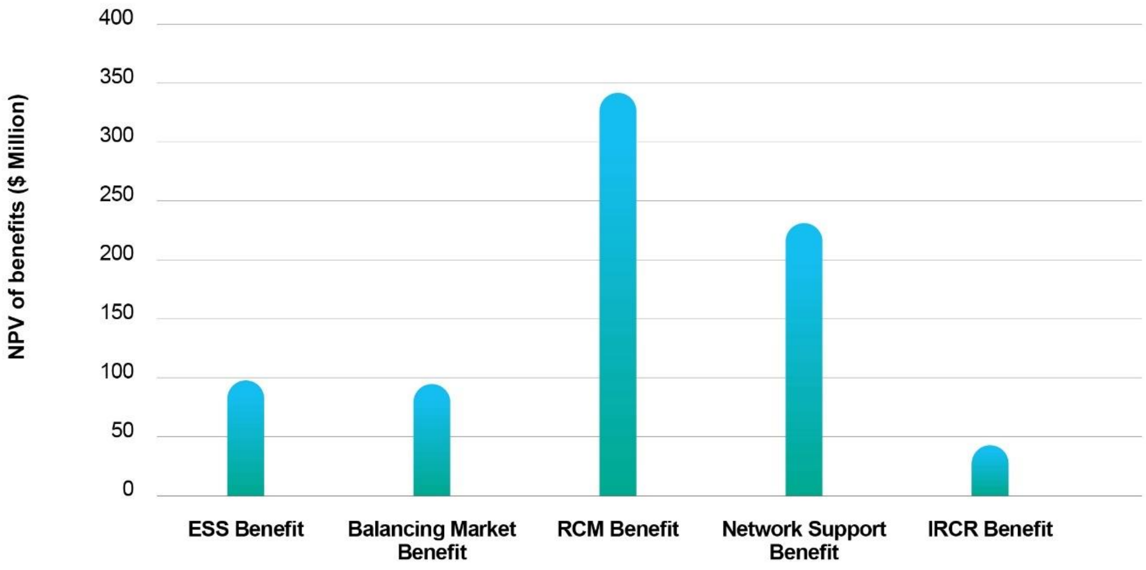
[56] It should be noted that the modelling undertaken in this study only considered BTM batteries. The VPP could also employ direct network connected (front of meter) batteries as part of its portfolio. This may be tested within the Project Symphony pilot.

Figure 19: NPV of benefits by service category (Scenario 1)



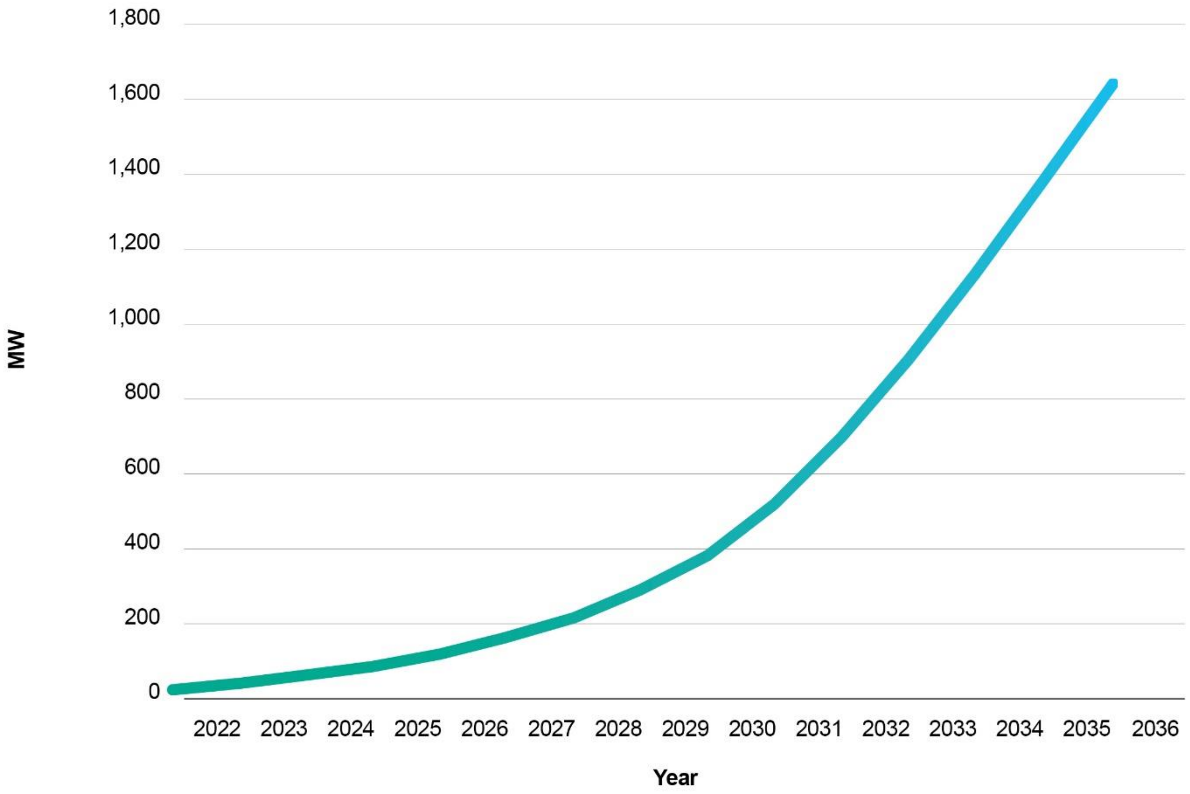
Source: OGW analysis

Figure 20: NPV of benefits by service category (Scenario 3)



Source: OGW analysis

Figure 21: Total economic potential of VPP-enabled BTM battery capacity (MW) through 2038



Source: OGW analysis

4.3 Emissions

The impact of the operation of the VPP on emissions over the study period was assessed through modelling undertaken by the Project Symphony Partners that examined the impact the change in demand determined in this study would have on emissions. Under the assumption that the number of DER assets (e.g., batteries and rooftop solar) in the SWIS is the same under the VPP scenarios and the no-VPP base case, that work determined that the overall impact of orchestration on emissions could be expected to be quite minor.[57]

The specific factors and their relative contributions to this outcome are not entirely known. However, at least in part, it is likely to be due to the fact that while the VPP orchestrates the operation of a *portion* of the batteries in the market:

- The total number of batteries in the market is assumed to be the same in the VPP scenarios as it is in the no-VPP base case scenario
- While the operation of the VPP batteries differ from those that are not orchestrated, this primarily results in:

57 This modelling of emissions reductions will be conservative to the extent that (a) the value created by orchestration results in a greater uptake of DER, and (b) the greater uptake of DER offsets operation of or investment in higher emitting generation plant.

  - A time-shift of only about 3 hours when the battery charges from the PV (from about 8 AM to 11 AM in the no-VPP base case to about 11 AM to 2 PM in the VPP case), and
  - A shift in the battery discharge rate, from a relatively slower rate over the evening and overnight hours to a faster rate in the earlier evening hours.
- In addition, it should be noted that if the marginal generation unit operating at the time the VPP batteries export to the grid is a central wind or solar plant, the net impact on emissions will be zero.

Taken together, these changes may not affect the types of generation plant running or their total output, which would have the effect of only minor changes in emissions.

4.4 Value creation and value capture

Scenario 2 reflects the impact of the VPP operator being unable to monetise the economic benefits that accrue to the network business from the operation of their fleet of VPP-enabled devices due to the lack of cost-reflective network price signals. Note that those price signals could take the form of cost-reflective network tariffs[58] or negotiated contractual arrangements available to the VPP for delivery of network support services where and when needed. This difference in (economic) value creation versus value capture results in lower overall financial flows to the VPP operator and hence lower amounts flowing through to its VPP customers, and because of that, lower overall take up. As indicated in Figure 6 above, Scenario 2 delivers over $50m less in gross economic benefits than Scenario 1. This is due to the lower take-up, despite the fact that Scenario 2 assumes that all VPP-enabled devices operate the same way they would have, had they been able to monetise the economic benefit accruing to the network business.

Scenario 4 reflects the impact of removing the estimated financial loss (opportunity cost) to a battery owner of not being able to use the energy in their battery to offset their own retail bill on those days when it is operated as part of the VPP.[59] Instead, on those days, this energy is discharged into the grid over a short space of time when prices are high. This financial opportunity cost – in effect, reflecting the retail price signal of $0.29/kWh multiplied by the amount of additional energy that is exported into the grid during peak price periods, net of any revenue that can be generated from the application of any feed-in-tariffs (e.g., the DEBs) – is clearly not cost reflective. In particular, the energy that is foregone by being discharged from the battery is likely to have been exported after any network peak occurs, and outside of when high balancing prices occur. Hence the true marginal price of providing that electricity via the grid will be materially less, possibly in the order $0.06-$0.08/kWh.

The disconnect between the retail price and the underlying economic costs of supply during these periods, everything else being equal, disincentivises customers to join a VPP, thereby lowering the overall economic benefits of the VPP. This is demonstrated by the fact that if we remove the financial loss (opportunity cost) to the owner of the battery:

[58] Such tariffs would ideally be both time-varying and locational such as a critical peak day tariff.

[59] For the avoidance of doubt, the financial opportunity cost will be dependent on a range of customer-specific factors and a range of factors affecting the electricity market on the days the battery is discharged into the grid.

- Take-up jumps up from ~325k in Scenario 1 (the equivalent scenario, but which includes the financial loss to the customer) to ~336k under Scenario 4; and
- Gross economic benefits increase from about $1.125b in Scenario 1 to about $1.188b in Scenario 4.

4.5 Commercial implications of results for VPP, participating customers and other parties

As can be seen from Figure 10 in Section 4.2.1 above, all scenarios produce net benefits for participating customers. The net benefit to these customers is comprised of:

- The proportion of the economic benefits that the VPP operator is assumed to share with customers; and
- Any financial benefit/cost stemming from the impact of the load changes on customer retail bills.

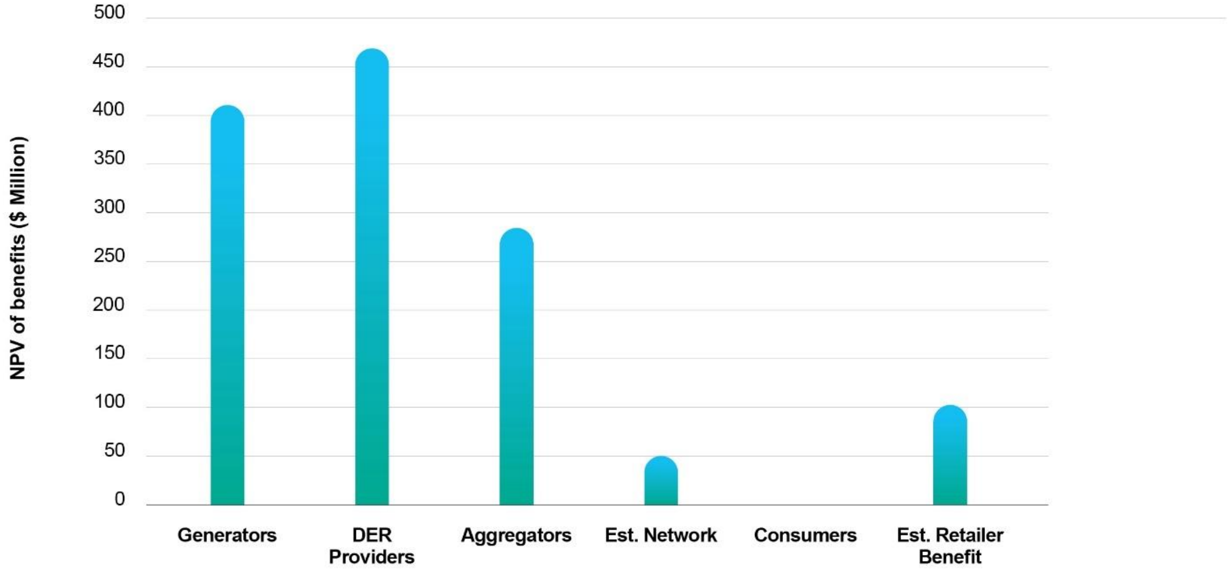
The retailer, as the operator of the VPP, also achieves net benefits in most of the scenarios. The only exception is Scenario 0, in which 100% of the economic value produced by the VPP is assumed to be transferred to the participating customers. It should also be noted that reducing the sharing ratio may not necessarily improve the financial outcome for the retailer,[60] as it would be expected to lead to less take-up by customers, which:

- Reduces the magnitude of the gross economic benefits that are available to be shared in the first place; and
- Reduces the number of customers over which upfront and fixed costs must be recovered.

Figure 22 below shows the estimated net benefit to the VPP assuming that all the economic benefits can be monetised, and the VPP operator shares those benefits 50/50 with the end customers participating in the VPP.[61]

[60] For the avoidance of doubt, for the purposes of this analysis, we have only modelled a small number of potential sharing ratios. It may be that there is a certain sharing ratio (or ratios) that allows the VPP operator to achieve net benefits.
[61] These are the assumptions underlying Scenario 1.

Figure 22: Estimated financial benefits of the VPP to different parties under Scenario 1



Source: OGW analysis

The following dot points provide some further information on the outcomes for each of the parties:

- Generators: For the purposes of this report, the outcome for generators assumes that the output from marginal generators is supplanted by the VPP, and those generators would have reduced marginal sales at which the operating profit is zero, causing no net cost to them. Scenario-based future market projections of half-hourly energy market prices out to 2040 provided by the Project Symphony Partners indicated that the difference between the base case (i.e., no orchestration) and the VPP case was marginal, at only about ~$0.85/MWh.
- DER providers: The outcome to DER providers is 50% of the full economic value monetised by the VPP (being the amount that is assumed to be shared with them), less the assumed direct incremental costs of connecting to the VPP ($150), less the increased retail bills they face (noting that the battery gets discharged over a short space of time, meaning that that energy is no longer available to offset the customer's retail bills).[62]
- VPP operator***:*** The value to the VPP operator is the economic value that can be monetised, less the amount that is assumed to be shared with DER providers (e.g., 50%), less the annualised set up and operating costs of the program.
- Network operator: Under Scenario 1, network benefits are monetisable by the VPP; as such, all of the network benefits produced by the VPP flow to the DER providers. The network

[62] Note that neither the initial cost of the battery (or its replacement at the end of its useful life) nor any maintenance or repair costs associated with its use have been included in this analysis. This is because all batteries included in the assessment were forecast to have been purchased even in the absence of the VPP in the information provided by the Project Symphony Partners that was used to construct the base case. This study only considered the incremental costs incurred by the customer to participate in the VPP. These are represented by the $150 connection cost and any opportunity costs incurred by the customer due to VPP operation reducing the ability of the BTM battery to offset the customer's use of grid-supplied electricity.

benefits that are shown in Figure 22 comprise the additional revenue that the network would receive from the volumetric charges associated with the increased consumption of DER providers for end uses in the evening and overnight that are required due to the battery being largely discharged in the evening peak hours by the VPP.[63]

- Consumers: As described above, under Scenario 1 all of the network benefits produced by the VPP are monetised by the VPP and shared in part with the DER providers. As such, none would flow to other consumers. By contrast, if the VPP operator is not able to monetise the economic value provided to the network operator (because price signals reflecting that value are not available, as modelled in Scenario 2), customers would get 70% of that value and the network operator would get the other 30% (based on the assumed percentage sharing outcome under the gain-sharing scheme).
- Retailer: The benefit to the retailer has been estimated based on the financial opportunity cost to customers (which reflects the higher retail bills faced by DER providers through increased grid consumption), noting that part of this flows through to retailers and part on-flows to the network business (a split of ⅓ to the network operator and ⅔ to the retailer has been assumed).

[63] Technically, the changes in energy flows on the network resulting from the VPP may change network charges marginally, however this has not been modelled.

5 Result Analysis and Commentary

This section of the report explores issues related to the modelling, its outcomes and aspects of the actual operation of the VPP in the market.

A key aspect of the value of the VPP is its ability to access and combine value streams that are not available to customers — particularly small customers — termed value stacking.

A feature of the design of the WEM is the use of the Reserve Capacity Mechanism (RCM) which provides value to market participants for bringing capacity to the market. The payment for the capacity is independent of the subsequent use of the capacity as long as the participant makes the capacity available in the day ahead STEM and RTM — that is for real time energy dispatch and for use in the frequency control ESS markets.[64]

The VPP is therefore able, under certain circumstances, to access more than one value stream at a time, which is generally referred to as value stacking. For example, the VPP can use BTM batteries to garner income from the RCM, the RTM and the network via mechanisms such as prudent discounts and reference services. The WEM has a co-optimised RTM whereby the market participant makes its capacity available for specific services and the dispatch optimisation enables the specific services as they are required, and where the VPP offer is lower than that of other parties for the service.

Under the co-optimisation approach, a dispatched facility can only provide one of the services for a specific parcel of energy. The modelling undertaken for this report assumes that the capabilities of the VPP are taken up for whichever service has the higher value in each trading interval those capabilities are offered.

Importantly, for certification under the RCM,[65] storage must be available for dispatch in the real time markets for four hours during a defined period of a trading day, which will normally coincide with the highest demand periods of a day.

Battery capacity that has not been certified under the RCM is still able to be dispatched in the RTM — under the same optimisation conditions — however, the four-hour availability obligation does not apply. The VPP is therefore able to offer these services whenever its participating customers can physically deliver them. For modelling purposes, we have assumed that storage devices will be charged during low demand periods when prices are expected to be low.

The other DER devices are modelled in the ESS markets and for the demand-side value of shifting their load out of peak periods and into the middle of the day when prices are lower. The demand-side benefit accrues by shifting the loads and the additional value from the VPP is the ability to use the loads for contingency ESS. This is based on their ability to draw load or to be switched off as required.[66] Where the provision of a service includes specific obligations — such as RCM

---

[64] Note that to participate in the ESS markets, the participant will need to meet the requirements that are specific to those markets.

[65] It should be noted that no rules currently exist for RCM certification of an aggregator. However, the modelling assumes the VPP can capture capacity value using the same rules as proposed for storage. Alternatively, a large retailer such as Synergy could dispatch the VPP in a way that would reduce capacity payment obligations (thereby monetising the economic value of the VPP capacity).

[66] Note that hot water loads have a period after heating is completed when they cannot draw loads, even if enabled. This “blackout” period is included in the modelling.

participation — the ability to optimise the use of the assets in the VPP is limited to the co-optimisation offered in the market. In this case, the optimisation is limited to the price of each service and which of the RTM services is offered.

Where the capacity is not required to meet RCM obligations it can be used more flexibly, including in the RTM and to support networks, where possible. For example, a storage device could provide network support to defer or avoid an augmentation but also be paid for the energy dispatched into the market as a result. In these situations, the potential avoided network cost due to VPP activity is modelled as an addition to RTM value.

Experiences reported by VPPs in the NEM note that contingency ESS is a lucrative market for DER (and particularly for storage) but they also contract with networks for support and provide energy into markets. The modelling approach used here is therefore consistent with other markets.

Note that frequency control ESS regulation is offered less often by VPPs operating in the NEM. Oakley Greenwood is aware that at least one VPP provider[67] has offered this service in the past but stopped due to customer concerns. In addition, there are reports citing increased degradation where a battery is used in this mode.[68]

The Project Symphony Partners included regulation services in the modelling on the assumption that technical and consumer issues can be resolved as it is expected to be a high value service. In fact, as noted above, the value of the VPP is markedly reduced if regulation lower is not included. We note, however, that the functionality to provide ESS regulation is not included in the initial Project Symphony VPP pilot but may be added later. It has been modelled in this study based on its economic value and the fact that it is possible from a technical perspective.

It follows from the statements made in Table 6 below that the optimisation of value for the VPP is in developing accurate models for the dispatch process so that the appropriate facilities can maximise their participation in the provision of these services. A static, economic model is unable to fully illustrate this and is limited to providing scenarios for analysis.

---

67 Private discussion.

68 Battery degradation is discussed in, inter alia, Peppaen et al Considerations for Energy Storage in Distribution Planning, CIGRE Session 2020, available from e-Cigre.org, Deakin et al Combined Solar Photovoltaic and Energy Storage Sizing in Constrained Distribution Networks, 25th International Conference on Electricity Distribution (CIRED) 3-6 June 2019 and Darlene Steward Critical Elements of Vehicle to Grid Economics, National Renewable Energy Laboratory Berkeley Lab 2017., Tesla, who operate a large VPP in South Australia notes that their devices are covered by warranty where they are used as part of a VPP and they only offer ESS contingency services and energy – Tesla presentation on its SA VPP during the IEA seminar 29 July 2021.

Table 6: Value-stacking available to a VPP

Primary Service	Stackable service	Comments
Capacity as part of the RCM	RTM (i.e., energy, contingency ESS and regulation ESS). Eventually RoCoF.	This is an obligation for receiving capacity credits. Only one of the stackable services is selected at any one time for a particular parcel of energy.
Network Support	RTM (i.e. energy, contingency ESS and regulation ESS). Eventually RoCoF.	When not required for network support, the energy can be offered into the RTM for dispatch (see note above regarding co-optimised dispatch). When needed for network support, the energy can be rebid to only energy dispatch — at a low price — to gain income from both services.
Real Time Markets (RTM)	None, except as noted above in the row on network support. The RTM co-optimises participation in energy balancing and the ESS markets; contingency raise, contingency lower, regulation raise and regulation lower.	A specific amount of capacity can only be allocated to one of the RTM during a trading interval. Therefore, while a participant can offer into all the markets, the values within the RTM are not stacked. Note that participation in each of these markets requires meeting the specific requirements of each market.

One area of additional and potentially conflicting value is the customer's own use of any DER device, and this is particularly true for a BTM battery. In general, customers purchase a battery associated with a PV facility to time-shift the output of their PV system so that they can reduce their overall usage of grid energy, which reduces their bill at the rate of their retail tariff. In addition, there is the benefit - though it is an order of magnitude smaller - of being able to avoid interruptions to supply.

Therefore, customers will likely need to be compensated for the energy removed from the battery by the VPP operator at the retail tariff rate (or higher) to be consistent with the reduced ability to time-shift their PV. This forms the basis of the opportunity cost used in the financial modelling that underpins the estimation of VPP take-up in our modelling. It is worth noting that we are not taking any similar factor into consideration regarding the other DER devices. Rather, we have assumed that the re-direction of their consumption and use profiles can be accomplished without any loss of amenity to the customer. This is likely to be a very safe assumption for water heating (as long as the tank size is sufficient to ensure an adequate supply of hot water). It may be less so in the case of the cycling of air conditioners and the charging of EV batteries. In both cases, the customer may have a higher perception of the potential risk of reduced amenity or convenience than would be the case with controlled water heating. This may reflect more than a simple monetary consideration on the customer's part. The transfer of management/control involved and its implications for the customer's quality of life may need to be addressed in ways other than a cash incentive.

This is a trade-off that the VPP will need to manage, and which may require other approaches. For example, the Tesla approach[69] is to reserve 20% of the storage capacity for the owner's use, whether that be for outage ride-through or energy displacement during periods of high household load.

5.1 Impact of retail pricing structure

In many ways the value of the VPP is how it allows the efficient price signals that are available in the RTM — and via contracts with networks — to be provided to customers. There are a host of reasons why retail prices, particularly those for small customers, may be inefficient. One is that customers want simple prices that they can understand and do not want to be exposed to complex and sometimes conflicting price signals. The ability to translate such complex price signals into a structure that customers can understand and respond to is one of the main capabilities that retailers, aggregators — and VPP operators as a special form of aggregator — bring to the market.

Inefficient pricing can both benefit the VPP, as discussed above, and harm the attractiveness of the VPP. It can benefit the VPP by creating value streams that can be offered to customers that the customer might not be able to access on their own (because cost-reflective price signals are not available to end customers). However, inefficient prices such as flat, all-in tariffs also reduce the attractiveness of a VPP arrangement to the extent that the ability of the VPP to access DER services in response to economically efficient price signals will need to compete with the value that the customer could obtain by using the DER to reduce their consumption of electricity from the grid at retail tariff levels.

For example, if a customer faces a flat price, they are likely to operate storage and other devices based on convenience and the implications of that price structure – namely, that energy is 'worth' the same amount regardless of when it is used. This is inefficient from an economic viewpoint. The VPP provides a clearer price signal to the customer – though one that will still need to compete with the retail tariff. The customer will weigh up the VPP offer in light of other costs to them — including any change to convenience — such as whether the use of a storage device in the RTM prevents their personal use of that energy to offset retail prices late in the day.

If the retail price structure becomes more cost-reflective, it could be expected that the customer would value their demand shifting and their own use of storage more highly, reducing the likelihood they will make it available to the VPP. This is a good economic outcome. In this case, the benefit of the VPP will be in the aggregation, allowing the customers to participate in markets and to access pricing that would otherwise be unavailable to them. The VPP may also add value to the customer in how they make certain technologies available (e.g., their bundling of technology in the offer) and their ability to reduce the need for the customer to be proactive in decision-making regarding their energy consumption and export (e.g., the provision of a management function).

However, a VPP can be used by a retailer to provide greater flexibility in developing retail products (pricing) that overcome the limitations of regulated retail pricing arrangements. Examples include

---

[69] See footnote 56.

cost pass through products with low margins that give customers incentive to respond to upstream price signals (where available), and higher margin products that reward customers for allowing the retailer to use customers' DER assets to manage the retailer's exposure to upstream price volatility.

5.2 Regulatory, commercial and other barriers

This section of the report deals with matters other than the modelling and is based on the general experience of Oakley Greenwood and our reviews of the SWIS. Given the time available and the changes to the WEM this commentary is focused on the information in the design documents published by EPWA and the information provided by subject matter experts from the Project Symphony team.

VPPs are being trialled in several jurisdictions. Related approaches, such as connected microgrids, embedded networks and local energy markets, are also being trialled and provide some insights into some of the issues facing VPPs in WA.

In most cases, the focus of the VPP is on high-value markets that are easy to access. These are often support for networks and participation in ESS, particularly contingency services where the value accrues from enablement rather than use.

5.2.1 Complicated registration and technical requirements

Participation in wholesale energy markets is expensive and complicated. The focus tends to be on larger players and a smaller number of connections. This is an area that has been identified as a barrier to participation for smaller participants. In the NEM this has led to the development of additional market participant categories, for example, the small generator aggregator and intermediary in the NEM. The key role of the aggregator is to bypass complicated registration processes and access efficient pricing:

> *"The new Small Generation Aggregators will be financially responsible for trading the output of small generating units in the NEM. They will be able to add small generating units to their portfolios in a similar process to how market customers currently add loads.*
>
> *By giving small generators more options there should be a more efficient use of generation capacity in the NEM. This may lead to a marginal long-term reduction in pool prices and thus possibly a reduction in the prices faced by consumers in the long run"*
> *(AEMC determination, 29 November 2012)*

More recently, the NEM has allowed aggregators of demand response to participate, again expanding small participant access, and providing a potential source of demand response capabilities that previously could only be capitalised upon by the party acting as the retailer to the customer.

The VPP is similar to an aggregator in this regard: it is able to provide a single contact with the market operator for registration, communications and receipt of dispatch instructions.

5.2.2 Technical and administrative requirements that prevent smaller DER from participating in the RCM

Factors that prevent small volume customers from participating in wholesale electricity markets include:

- Cost of wholesale market participation. There are significant fixed costs in being a market participant (e.g., prudential costs).
- Communications. Small participants do not have the equipment to receive and respond to dispatch and other instructions from the market operators, for example, the ability to respond to AEMO AGC signals. The VPP is able to provide the necessary communications and gateways to allow small-scale facilities to be operated and managed.
- Metering. Some markets require specialised metering, for example ESS markets. The need to have the required metering is not always possible on small-scale facilities but can be emulated on VPP gateways. This is currently being examined in the NEM and the responses of VPP participants indicates that some have solved these issues.

5.2.3 Customer involvement in markets and price signals

Customer adoption of efficient and coordinated dispatch practices is not assured, even in the presence of efficient pricing. Research shows that customers are less inclined to follow pricing changes unless they are explicitly approached, encouraged and assisted to understand them. Even in that case, a compelling reason to adopt a preferred approach can be required. This is therefore a key role for VPP providers and customer-focused retailers and aggregators: to provide customers with an approach to optimising their energy use in an integrated way with wholesale market drivers that are easy for the customer to understand and action.

Even if pricing is cost reflective at the wholesale level and networks adopt cost-reflective pricing, there will still be inefficiencies at the residential level due to averaging effects and customer choices. Only the most motivated customers will track energy prices at their household for more than a few days.

It is more likely that most will either adopt a “set and forget” approach to household efficiency based on some simple rules or prefer another party to manage their devices to provide an optimal outcome for them. The key focus will be to provide the optimal outcome for customers based on the prices charged to them and the sharing of any benefits available from the operation of their DER as part of the VPP.

Recent research by Upowr,[70] funded by ARENA, on customer attitudes regarding the take-up of VPP systems indicates that a marketing and commercial focus on the customer is required:

> *“The willingness and interest of households to participate in orchestration programs has also been lower than expected. While these participation numbers are rarely made public, our conversative estimate based on available literature and conversations with key stakeholders,*

[70] UPower “Customer Segmentation Research and Design for Orchestration Programs”, ARENA April 2021. Pages 54 and 55. Available from the ARENA website.

> *suggest that as little as 10% of households who have installed a battery system are participating in an orchestration program. When left unorchestrated, home battery systems can cause harm to the electricity grid and subsequently, the households needing electricity from it, due to the speed and quantity of energy it can abruptly release back to the system. In early 2019 following an activation of the Reliability Emergency Reserve Trader mechanism, Reposit Power reported that unorchestrated batteries were charging from the grid at a point in which the grid needed a drastic increase in supply (reported to have contributed to an additional 350 homes going without power).*
>
> *Challenges relating to customer recruitment and participation in orchestration programs have been well documented in previous ARENA funded trials and projects. We see the challenges play out in the following key ways:*
>
> - *Fragmented customer journey with narrative inconsistencies and missed value creation opportunities due to mismatched incentives;*
> - *Values misalignment and product complexity in program design (Who are the programs being designed for and why? What are the benefits of the program? Do they align with the kinds of benefits households want to receive?);*
> - *Complex messaging in program recruitment; and*
> - *Opaque personalised benefits."*

This research indicates that the design of the reward system, the communication approaches and messaging, and the community positioning of the VPP are all critical to its success.

5.3 Risks DER may pose to the wholesale market and net contract positions

Unmanaged DER – epitomised by rooftop PV that cannot be remotely managed, but also comprising rooftop PV with batteries that are not orchestrated – poses volume risk in the wholesale market. Because PV relies on sunlight, its impact on consumption and export – and therefore operational demand – is that it adds another variable to the daily load profile. In aggregate, however, its impact has been shown to reduce operational demand in the middle of the day.

This has changed the load profile that generators are dispatched to address and their exposure to the balancing market. While this poses a challenge for wholesale market participants, it is not a different type of risk from what they have always faced – namely, volume and shape risk. It does, however, significantly add to that risk, and particularly so where participants have entered into long duration contractual arrangements that cannot easily be changed.

Because a VPP (via its dispatchable BTM batteries) can provide some management of the consumption and export of the end customers in it, it can help manage the volume/shape risk of unmanaged DER. This may not provide total mitigation of this risk in the case of long duration contracts entered into prior to the take-up of DER, but it will be an improvement and will comprise an easier load to contract for when older contract positions roll off.

5.4 Notes on future cost reductions in VPP costs for communications and management

Participation in the VPP requires systems for communication with and management of devices owned by the customer. These can be expected to reduce in cost as VPPs and customer participation increase. This is a normal technology life cycle. While there are current discussions on the best approach for these issues, it is likely that a range of alternatives will emerge. For example, Node1, a product developed by Intel and Indra, combines a gateway device with API elements providing remote management capability without the latency issue. Like most technology developments, the issues are not binary and multiple options emerge.

The tools for communicating between the devices are becoming increasingly ubiquitous as communication providers seek to capitalise on markets. Competition in this space — particularly cloud-based services – is expanding as more providers emerge. The cost of communication is therefore likely to decrease. For example, remote metering was initially set up using specific communication circuits — such as Silverspring in Victoria — but within a short period of time the cost of using existing telephony or broadband based services removed the need for specific telecommunication access.

Similarly, the gateway or other approaches for managing DER devices will become more open and less expensive over time. Many of the storage devices already include management systems, many with gateway or communication built in. It can therefore be expected that this will progress as interest in aggregating these devices increases.

The costs of the VPP can be material and significantly reduce the expected benefits to proponents and customers. A team comprised of Synergy and Oakley Greenwood personnel examined the current cost structure of the Project Symphony pilot and posited a range of potential cost reductions, including at what stage during the study that these cost reductions were likely to take effect. The results of this small study were tested with the stakeholder group and, after agreement, were included in the cost benefit analysis.

5.4.1 The risk of incompatible communication systems

A specific concern for the development of VPPs is the potential for 'Balkanisation' of load management and communication systems. For example, Tesla currently includes a control system for their batteries that links to a proprietary system operated by Tesla. This could potentially limit the access to homes by other VPP providers or aggregators — particularly to individual devices.

Two pressures reduce the risk of Balkanisation:

1. Development of standards. As an example, the AS4755 standard, (which is now replaced by AS 4755.2 and AS 4777.2) – which is based on a similar international standard – led to the widespread inclusion of the communications protocol and controls in air conditioners, fridges, washing machines, etc.

   The inclusion of the necessary systems as standard in devices imported into Australia allowed Energex to offer its PeakSmart programme, which offered a small payment if purchasers of air conditioning connected their systems to the existing energy power line control circuits. This allowed Energex to cheaply manage peak demands in its service area.

A more complete standard is currently being developed for Australia – the Common Smart Inverter Profile Standard Australia[71] - which is based on the IEEE standard. This will allow the adoption of improved communication approaches in the future.

By having a standard that is widely adopted, manufacturers can incorporate the necessary hardware and software in this equipment to make it VPP ready. The addition is relatively cheap when included in the mass production of goods.

2. Consumer pressure. If aggregation and participation in VPPs is widely available, consumers will prefer equipment that is able to participate if the cost is not too much greater.

   As a result, installers and suppliers will begin to offer the VPP ready products in preference to 'dumb' devices. It is likely that these devices will increasingly use standardised protocols.

With increased use of additional devices, such as pool pumps and storage heating in VPPs, control devices or devices with remote management capabilities incorporated can be expected to emerge.

This does not remove the existing cost problem for the VPP being proposed by the Symphony Partners, nor does it mean that the issue will necessarily be resolved quickly. It does imply, however, that the costs for VPP operations will improve with time and therefore the current analysis is likely to be conservative over the longer term.

[71] This standard is being developed by the DER Integration API Technical Working Group as a local application of the Common Smart Meter Inverter Profile developed in the USA, which leverages existing standards and models from both engineering (e.g., AS/NZS 4777.2) and communications (e.g. IEEE 2030.5). A report on the proposed standard and model was published in September 2021 by ARENA – common-smart-inverter-profile-australia.pdf (arena.gov.au)

6 Opportunities for overcoming barriers and enhancing the ability of VPP operations to deliver value

This study has assessed the nature and potential level of economic benefit that a VPP can deliver to the SWIS. Project Symphony will provide information on the real-world factors that influence the degree to which those benefits are likely to be realised and distributed, including the performance and cost of VPP technology, customer take-up of VPP offers, customer acceptance of different types and levels of VPP orchestration, the operation and interaction of policy, market rules and regulations, and the roles and responsibilities of the various parties within the electricity sector.

The modelling undertaken in this analysis suggests the following items are likely to be important, further considerations regarding the design and operation of a VPP in the SWIS:[72]

- **Targeting battery customers:** As noted in Section 4.2 above, the modelling indicates that it is the battery that contributes the majority of gross economic benefits of the VPP. Therefore, in terms of targeting customers, the battery effectively becomes the gateway to enabling the potential economic operation of a VPP within a customer's property, or put another way, absent a battery, there is little benefit in targeting a customer for inclusion in a VPP.
- **It will be important to be able to monetise all economic benefits:** Simply put, the more benefits that can be monetised the more value the VPP can offer, which in turn will be likely to increase participation. There are opportunities for increasing the number of benefits that can be monetised by a VPP in both the ESS and network support portions of the value chain. Ideally, Western Power would signal, via a cost-reflective price signal, the value a VPP can provide to their network in the long term. This could be done at a spatial level, and for the avoidance of doubt, these price signals do not necessarily need to flow through to all end customers. The price signal could also be sent via a prudent discount, locational reference service tariff or alternative option contract.
- **Non-cost reflective retail prices, particularly as they relate to the operation of the battery, need to be overcome:** Consideration should be given to ensuring that there are price signals in the market that reflect economic costs and thereby counteract the perverse incentive customers currently have to retain energy in their battery during otherwise high price periods in the balancing market in order to offset their own grid consumption that occurs:
    - Outside of peak (network) demand periods;
    - During periods that generally reflect lower prices in the balancing market, but that are charged to the customer at the same price at all other times; and

  In addition, feed-in-tariffs should be structured and set at levels that reflect the value of energy exported to the wholesale market, including when that export occurs.
- **Attention will need to be paid to VPP technology costs and the potential for reductions in those costs**: The costs in the early years of the study timeframe for setting up and operating the VPP make its net economic benefits marginal. Anticipated reductions in these costs will significantly improve the VPP's cost-effectiveness over the full study timeframe. It

[72] All of these issues would apply to any party seeking to operate a VPP in the SWIS.

will be important to ensure that developments in the relevant technology are monitored carefully so that the anticipated cost reductions (or, potentially, deeper ones) can be gained as the technology advances. In this regard it is essential that the ability to exploit new technologies is not precluded by procurement activities that reduce optionality. As an example, the use of API for communications and management, when they become available, is expected to provide a significant cost advantage compared to the use of the Gateway device that has been assumed to provide this functionality for the first several years of the VPP's operation.

- **The ability to provide regulation services deserves attention in the Project Symphony pilot:** The modelling clearly indicates that the VPP will be cost-beneficial if the only ESS it can provide is contingency control, However, it also revealed that, everything else being equal, the ability of BTM batteries to provide regulation – and particularly regulation lower service – is likely to be a significant source of value to the VPP and the electricity supply chain. This is due to the significantly higher current and forecast value of regulation lower services as compared to regulation raise services or to contingency raise or lower services over the forecast period. Based on this, the incremental costs of enabling this functionality, and customers' acceptance of allowing their battery to be enabled to provide these services, are issues that should be considered for investigation in the Project Symphony pilot.

Appendix A: Sources of value included in the modelling

OGW was asked to consider 19 different ways in which a VPP could produce value to the electricity supply chain and/or participating customers. Some of these concerned the same service but from the perspective of different parties.

Not all 19 ways were modelled. Two considerations went into deciding whether a specific source of value would be modelled and if so how:

- The cost-benefit assessment was specified to be undertaken from an economic perspective (i.e., the cost-benefit assessment was to evaluate "… the total social costs and total social benefits of DER that are expected to be realised at a system level, where social costs and social benefits accrue to those who provide DER assets, aggregate DER assets, generate, transport and consume electricity in the SWIS and are measured in present value terms".[73] It is important to note that, because the retail electricity tariff is an all-in price signal and is not reflective of how changes in a customer's export and consumption behaviour affect the various costs incurred in the different parts of the electricity supply change, the retail tariff cannot be used as the price signal against which a change in total social benefits or costs can be calculated.
- The benefits were to be created by a VPP. OGW was requested to note that Project Symphony "… is aimed at developing a proof of concept for integration and orchestration of virtual power plant (VPP) assets within the South West interconnected System (SWIS)"

The words 'integration' and 'orchestration' are both important in defining a VPP operation as distinct from an energy management service. The VPP orchestrates (i.e., coordinates) the export (and, to a lesser extent, consumption) behaviour of multiple end users in concert with and in response to the operating characteristics and capital and operating costs of the electricity supply system. By contrast, an energy management service coordinates the export and consumption behaviour in response to the end user's retail electricity tariff.

In our proposal we re-grouped the 19 sources of value based on the specific value stream (i.e., the source of value within the electricity supply chain) to which each relates. The table on the following pages shows which value stream each of the 19 sources relates to, and explains how we modelled the benefits that could be created from those sources that produce economic benefits from the operation of a VPP. The table also notes which of the 19 sources that either do not involve economic benefits or do not reflect the operations of a VPP.

[73] The request of OGW also specified that the amount of DER benefit created by the VPP that could be monetised by different parties (including DER providers, aggregators, generators, network service providers and consumers) was also to be determined. This has been done and reported on based on an assumed sharing of the economic benefits between the VPP operator and end customers. The level of sharing used in the modelling took into consideration the financial return to the end customer which was assumed to be determinative of their decision to participate in the VPP.

	SoW scenarios		
No	Description	Value stream	How treated in the model
1	Capacity credits: certification and operation of DER for the provision of reserve capacity.	RCM participation.	Modelled using RCP the ability to dispatch BTM batteries that are orchestrated by the VPP in compliance with the requirements of the RCM. The impact on wholesale market customers' total IRCR liability has also been modelled based on the load profile impact of the unmanaged operation of non-orchestrated batteries and the shifting of certain residential loads by the VPP to occur only at prescribed times (e.g., the impact of shifting water heating and pool pumping loads from whenever they currently occur to non-peak midday hours). The latter impact is credited to the VPP, the former is not.
2	Bilateral contract market: transacting wholesale energy / ESS / capacity bilaterally between DER and counterparties.	Energy market participation.	Not modelled as (a) contract prices do not represent a contemporaneous economic value and (b) we do not have access to market participant's contract prices (they are confidential).
3	STEM: offering or bidding energy into the day-ahead energy market.		Not modelled as the STEM is used to adjust a market participant's net contract position for real-time market settlement one day ahead of the real-time market auction and the STEM price is correlated to the real-time energy price.
4	Real time energy market (bi-directional): offering (generating) or bidding (consuming) energy into the balancing market.		Modelled using a scenario-based projection based on a future market scenario.
5	ESS regulation raise / lower: response to AGC signals to correct for small movements in frequency during a dispatch interval.	Dispatchable ESS.	Modelled for VPP-enabled batteries based on forecast prices. Regulation ESS was treated as the preferred ESS based on its higher economic value (on average) as compared to contingency raise/lower and the fact that the two services will not be enabled by the market operator simultaneously for a specific part of the VPP storage capacity. It was assumed that non-orchestrated batteries, and the 'other' DER devices that are assumed to be able to be managed by the VPP, are not able to be enabled into this market. The 'other' DER devices considered included water heaters, pool pumps, air conditioners and EVs.

	SoW scenarios		
No	Description	Value stream	How treated in the model
6 / 7	ESS contingency raise & ESS contingency lower: response to locally detected deviation to restore frequency to an acceptable level in a contingency event (e.g., loss of a large generator or load).		Modelled for 'other' DER devices (except battery whether VPP or not), based on forecast prices. Modelled for VPP-enabled batteries to provide an alternative economic valuation if their use for regulation services cannot be offered for some reason (e.g., the cost for providing the regulation service is too high or there are technical difficulties in meeting the requirements of regulation service provision).
8	ESS: rate of change of frequency (RoCoF): manage the rate of change of power system frequency.		Not modelled because (a) RoCoF has not yet been fully defined in the WEM and (b) no data is available on its likely timing, frequency or value.
9	Non-co-optimised ESS: a contracted service to help maintain power system security / reliability.	Other ESS such as voltage support and system restart: these are locational services; the potential for aggregation may be limited.	Not modelled as it is a service that is required locationally, requires energy to be consumed and is of very low value.
10	Constrain output and system restart services: throttling back or reducing DER generation to zero in an emergency either to prevent power outages or to support a system restart.		Modelling the curtailment of rooftop PV as a VPP option was not undertaken for several reasons including (a) the fact that the ability to do so as a backstop measure is being introduced through other measures, and (b) the exercise of VPP-orchestrated batteries and the load shifting of 'other' DER devices by the VPP will reduce the need for solar curtailment. VPP technologies – as manageable sources of generation – would be required by the system operator to be turned and kept off under system restart conditions.
11	Network support -- Contracted service to help manage network limitations.	Network congestion management.	Modelled for all VPP technologies at network LRMC for augmentation.
15	Network cost reduction (i.e., economic lens) over time due to the usage of DER to defer / avoid expenditure.	Network investment deferral.	Modelled for all VPP technologies at network LRMC for augmentation.

	SoW scenarios		
No	**Description**	**Value stream**	**How treated in the model**
12	Off market portfolio optimisation (market participant level) re: capacity.	Management of participant energy or demand: off-market service aimed at reducing the participant's overall costs, with some sharing of that reduction with the host facility.	The modelling approach used in Scenario 1 for the unmanaged operation of non-orchestrated batteries and the shifting of certain residential loads by the VPP to occur only at prescribed times will quantify the magnitude of this scenario.
13	Off market portfolio optimisation (market participant level) re: energy.	A change in load profile due to the exercise of load management by the VPP- rather than a load change bid into the market	The potential benefit to the market participant of this off-market service is quantified as part of Scenario 4. It should be noted that this will not be experienced as a payment but rather as a reduction in balancing market costs.
14	Off market portfolio optimisation (market participant level) re: ESS.	The result of a change in load profile due to the exercise of load management by the VPP- not a change in load provided in response to a market price signal	The potential benefit to the market participant of this off-market service is quantified as part of our approach to Scenarios 6 & 7. It should be noted this will not be experienced as a payment but rather as a reduction in ESS costs.
16	Network bill reduction (i.e., commercial lens).	The result of a change in load profile due to the exercise of load management by the VPP that reduces the market participants network use of system charges	Dispatch of the VPP to reduce the market participant's liability for network charges (except where the dispatch is in response to an economic price signal from the network - see Scenarios 9, 11 and 15) does not result in an economic benefit. Quantification of this benefit (i.e., change in network charges) can be undertaken as a post-model adjustment.
17	Self-sufficiency.	Services specific to a site: operation of DER to benefit the host w/o consideration of system benefits	This is not a VPP service as it does not involve the orchestration of the energy export and consumption of multiple sites within an interconnected electricity supply system. This will be addressed narratively. The key issue is the potential impact of very low battery costs on grid defection,
18	Back-up power.	Services specific to a site: use of the customer's battery to maintain supply in the event of electricity supply system interruptions.	Not modelled as the modelling assumes that the ability of the customer's battery to provide back-up power in the event of supply interruption remains the same whether the customer has joined a VPP or not. It should be noted that most VPPs reserve a portion of the battery's capacity for this purpose.

	SoW scenarios		
No	**Description**	**Value stream**	**How treated in the model**
19	Energy management services (customer level optimisation).	Services specific to a site such as optimisation of a customer's bill on an individual basis.	This does not constitute the provision of an economic benefit or the operation of a VPP. As an energy management service, this would involve actions seeking to optimise the export and consumption of an individual in reaction to the retail electricity tariff. It would not involve orchestration of the export and consumption of multiple sites in reaction to economic price signals market, is not a VPP function but rather is an outgrowth of optimising DER for the benefit of an individual customer in response to the retail price signal, which does not reflect the aggregate change in the total electricity supply system costs.