The State of the Art in Virtual Power Plants (VPP)

Power Session Webinar

19 March 2024

ENERGEIA

Agenda and Housekeeping

Agenda

- Consumer Resources
- Virtual Power Plant Economics
- Outlook for Virtual Power Plant Capacity
- Current Virtual Power Plants
- Takeaways and Recommendations
- Next Power Session

Housekeeping

This webinar is being recorded and distributed to all registrants along with this presentation

Add your questions in the chat. My colleague, Sara, is monitoring the queue of questions for the Q&A session

Speaker – Ezra Beeman, Energeia

Ezra Beeman

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Emerging Consumers and Virtual Power Plant Feedstock

Emerging Consumers

Emerging Consumer Energy Resources

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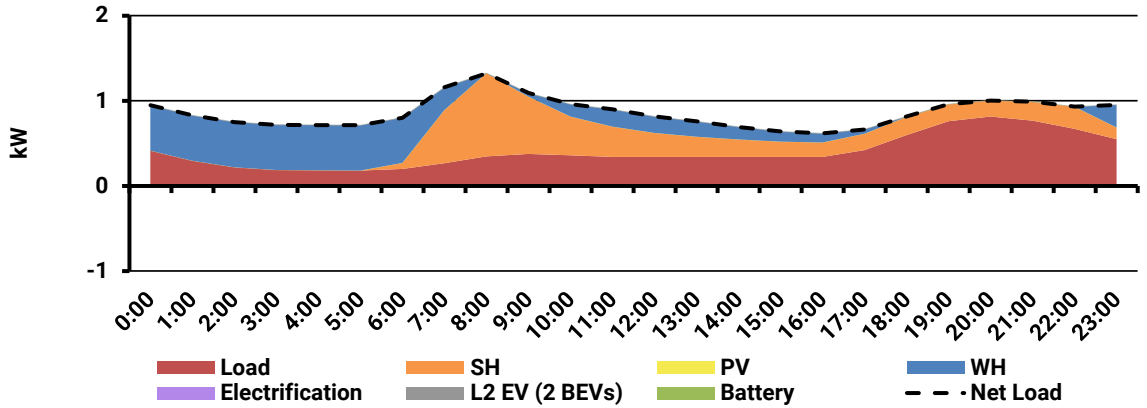
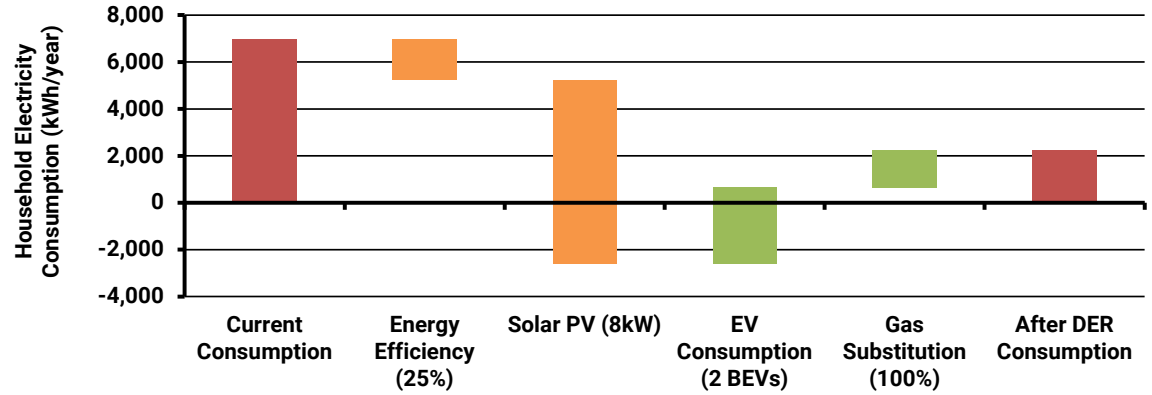
Consumer Decisions Impacting on Consumer and System Needs

Average Winter Day Residential Customer Profile (Victoria)



Source: Energeia Modelling.
Note: WH = Water Heating, SH = Space Heating

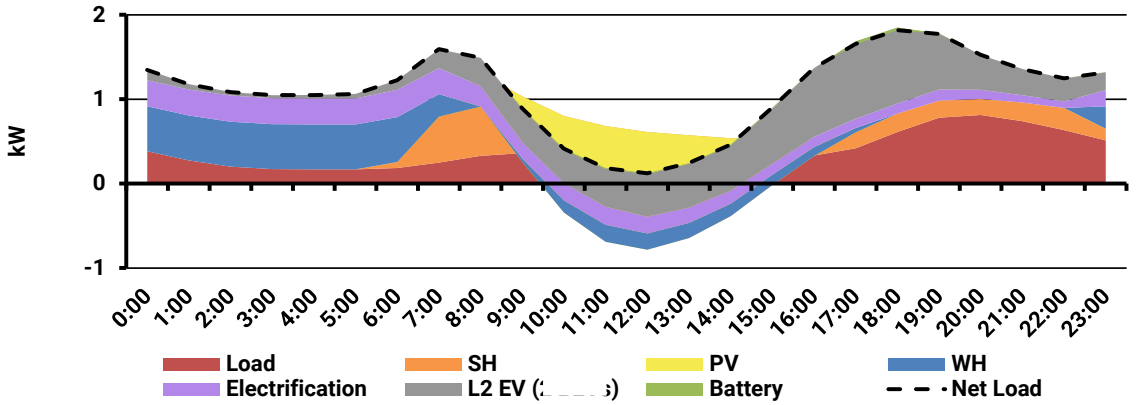
Potential Customer Decisions (Example)



Source: Energeia Modelling

- Customer decisions are radically altering their service requirements and optimal grid and system configurations
- Full electrification of transport and heating will increase premise consumption in Victoria by over 50%
- Solar photovoltaics (PV), storage and mobile storage could virtually offset that increase and more
- Most of these resources are flexible (excl. energy efficiency) and can be part of a Virtual Power Plant (VPP)

Illustrative Impacts of Customer Decisions on Load (Example)



Source: Energeia Modelling.
Note: WH = Water Heating, SH = Space Heating

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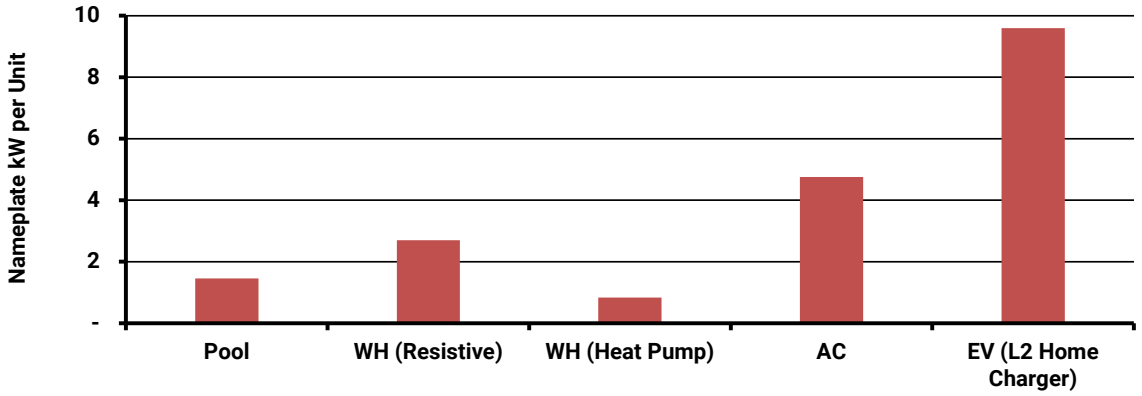
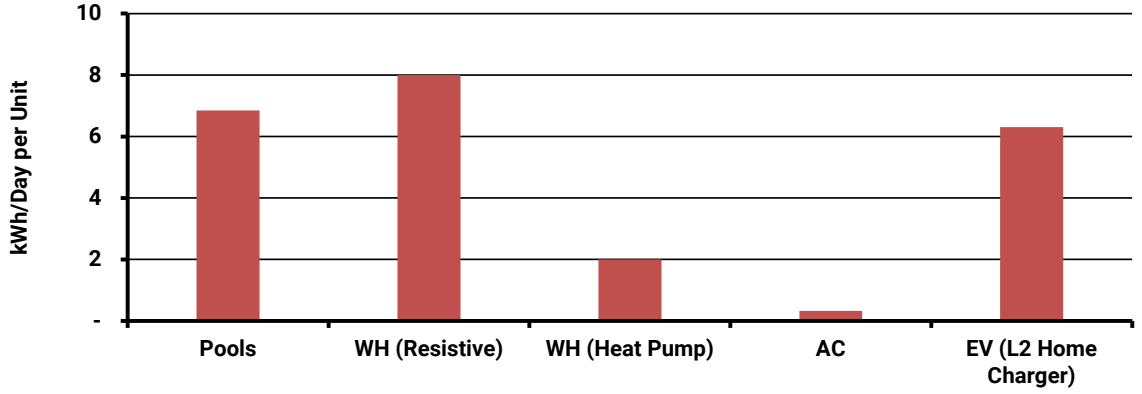
Consumer Decisions Impacting on System Planning

Load Demand Flexibility (Nameplate kW)



Source: UTS (2023), Energeia Modelling

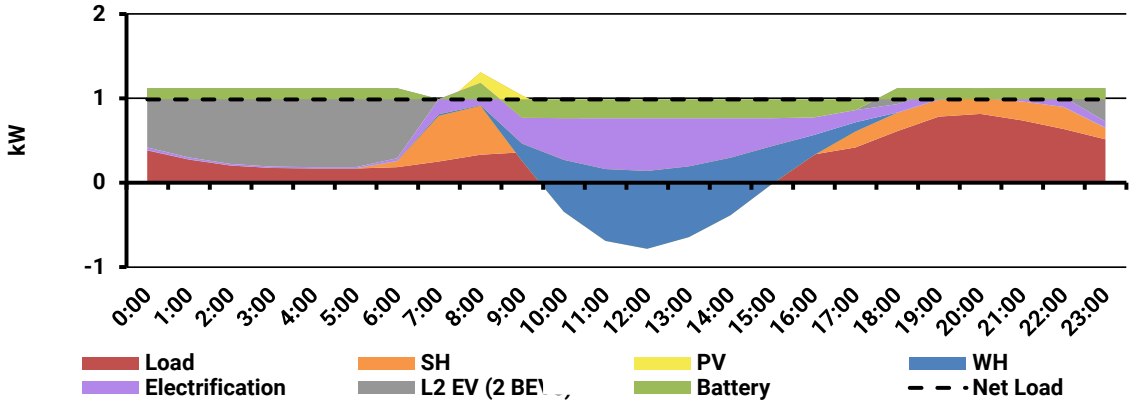
Load Energy Flexibility (kWh/Day)



Source: UTS (2023), Energeia Modelling

- For demand response, electric vehicles (EVs) followed by air conditioners (ACs) expect to be the most significant loads
  - Water heating can be 4.8 kW, but is typically charged overnight
  - In the future, water heating (WH) expected to occur during daylight hours to soak up PV
  - Pools and water heating the largest users of energy
  - Lower annual travel means EVs use is significantly less than in Australia than in other jurisdictions
- Orchestration, e.g. via a VPP, can result in a very low cost to serve outcome, e.g. for distribution utilities as shown in the example below

Illustrative Residential Load Profile Post Optimisation



Source: Energeia Modelling. Note: WH = Water Heating, SH = Space Heating

VPP Economics

VPP Benefits Case Study

VPP vs. Utility Scale Costs and Benefits (Storage)

VPP Other CER Incentive Analysis

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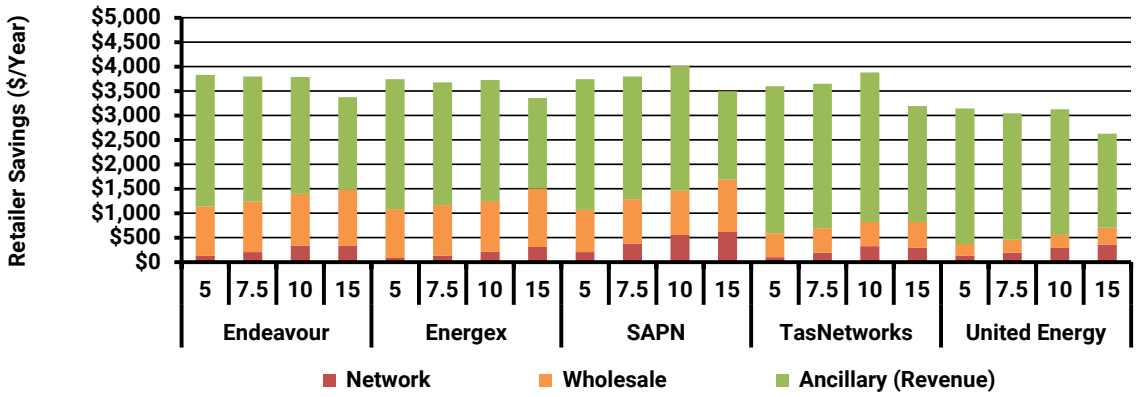
Virtual Power Plant Benefits per System in 2023 (Case Study)

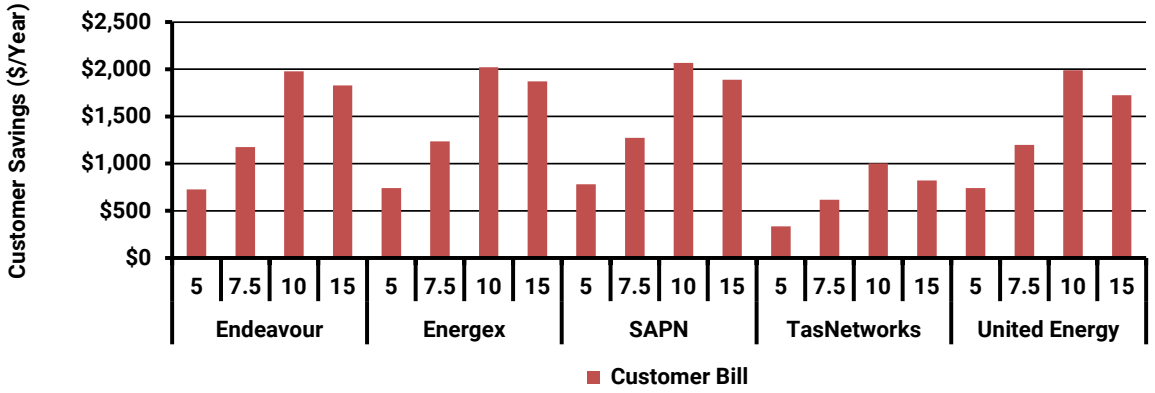
Estimated Theoretical VPP Revenues per Year by Stream



Source: Energeia Modelling
Notes: Assumes Tesla Powerwall, Numbers on x-axis reflect premise customer's annual MWhs

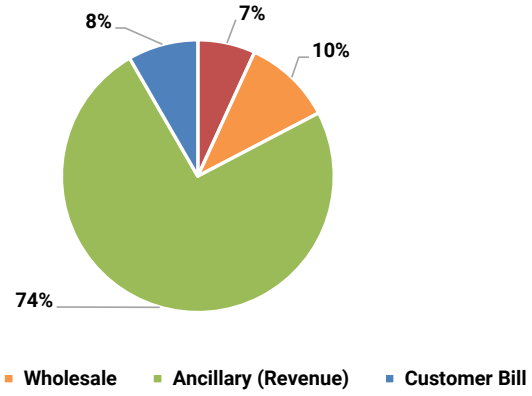
- Estimated value per year from a Tesla Powerwall 2 used in a VPP is shown at the top left for the system, and for the customer (excl. VPP payments) below left
  - Most estimated value from a value stacking based optimisation strategy in 2023 generated by FCAS markets
  - Wholesale cost avoidance second highest benefit
  - Network cost avoidance third highest
    - More cost reflective pricing would attract more service
  - Customer retail savings can be quite significant but much more dependent on annual consumption and tariff
  - Tariff and VPP benefits will converge as tariffs become cost reflective

Estimated Theoretical Customer Savings per Year



Source: Energeia Modelling
Notes: Assumes Tesla Powerwall, Numbers on x-axis reflect premise customer's annual MWhs

Average Revenue Stream Share of Hours (2023)



Source: Energeia Modelling
Notes: Assumes 5 kW, 14 kWh battery, e.g. Tesla Powerwall

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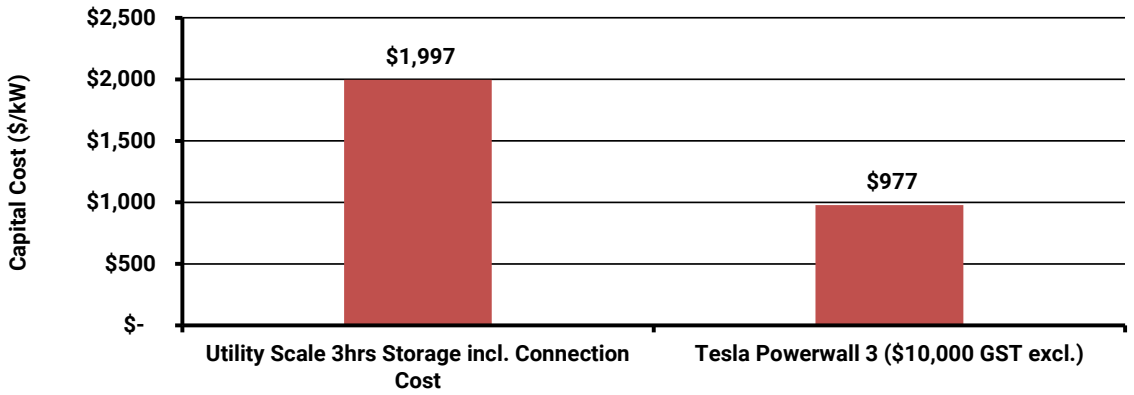
Decentralised Residential vs. Centralised Utility Scale Storage

Comparable Storage Costs ($/kW)



Note: Tesla Powerall 3 assumed ~$3,500 lower from avoided cost of 12 kW solar PV inverter
Source: Energeia Modelling, AEMO IASR (2023)

Storage Benefit Stream Comparison ($/kW/Year)

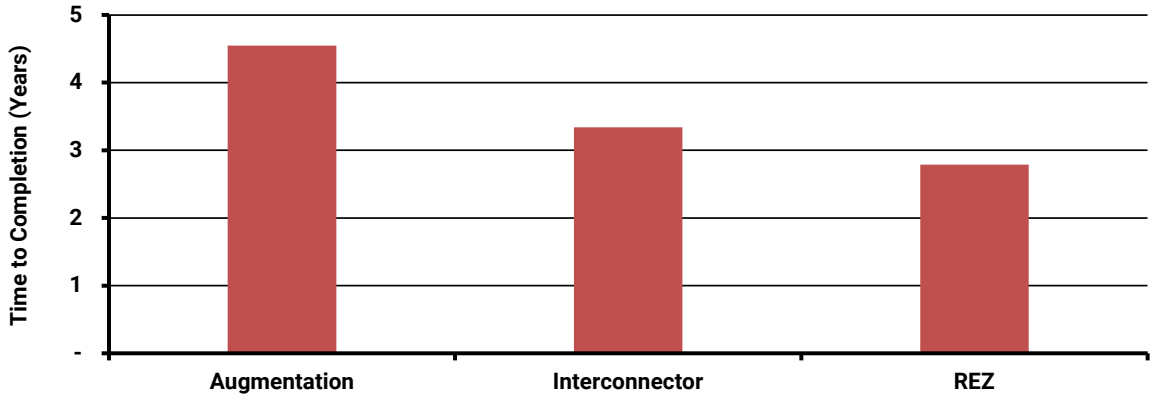
Storage Applications	Utility Scale Storage	VPP Storage
Market Services		
NEM FCAS Markets*	$2,000	$2,000
Energy Markets**	$80	
Transmission Services		
Peak Demand Management	$75	$75
Voltage Management	$5	
Distribution Services		
Peak Demand Management		$250
Voltage Management		$10
Retailer Services		
Network Charge Minimization***		$20
NEM Settlement Cost Minimization**		$80
Customer Services		
Customer / Host Backup		$50
Total ($/kW/Year)	**$2,160**	**$2,485**

Notes:
* = VPP expected to be able to participate in regulation market, but not yet
** = Energy market dispatch equivalent to retailer NEM settlement cost reductions
*** = Network charge minimization will ultimately be the same as peak and voltage service benefits
Source: Energeia Modelling

Source: Energeia Modelling, AEMO IASR (2023)

- Energeia's research found that residential VPPs can:
  - deliver over 15% more value to retailers than utility scale storage assets, e.g.
    - Minimization of network charges
    - Distribution grid services revenues
  - be 50% cheaper on an installed basis in specific circumstances, e.g. collocated with PV, and
  - have shorter lead times
- Retailers that harness VPPs will therefore achieve a competitive advantage over those overweighted to utility scale resources

Transmission Project Speed to Market



Source: AEMO IASR (2023),Note: REZ + Renewable Energy Zones

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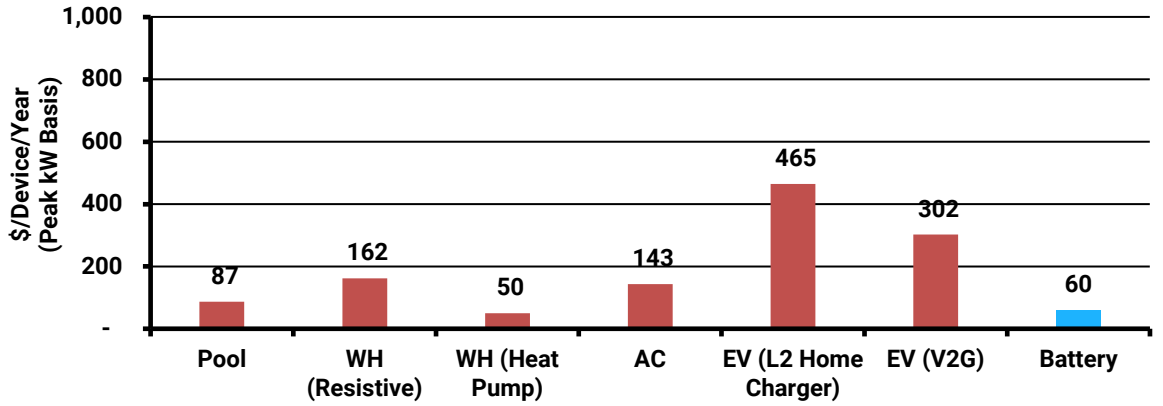
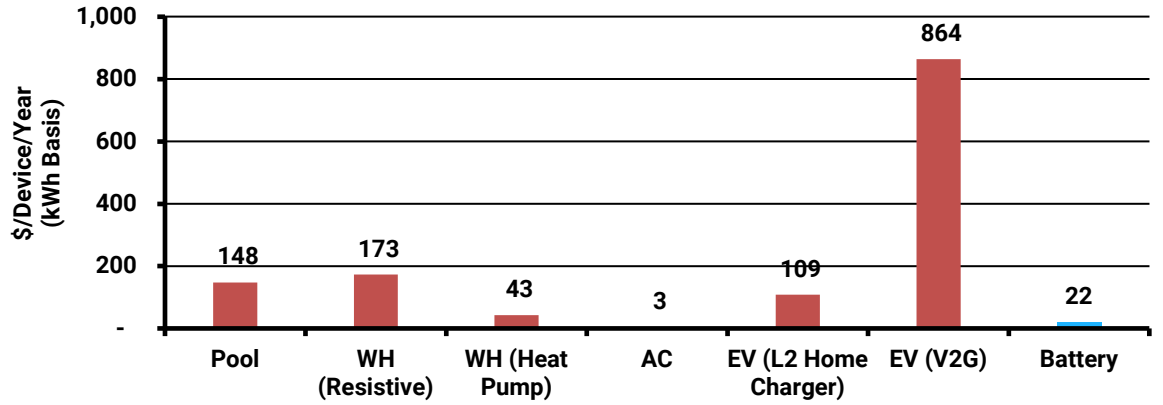
Estimated Value of Other CER Types in a VPP

Estimated CER Value by Type – Peak kW Basis



Source: Energeia modeling

Estimated CER Value by Type – kWh Basis



Source: Energeia modeling

- Energeia developed a volume-weighted average (VWA) $/kW-4hr storage incentive as a market average for a battery VPP
- We then divided it by the battery's power (5 kW) and energy (14 kWh), and scaled it based on each CER's 3-hour peak power or energy, respectively, to identify the relative value of other CER
  - AC peak kWs were reduced by 50% for cycling
  - EV Level 2 and V2G kWs and kWhs were reduced by 20% for opt-outs
- The results show that other CER, with the exception of AC energy shifting, are potentially more valuable than batteries
  - More analysis needed to confirm load reduction kWs available when likely to be needed, e.g. during price spikes and network peaks

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Outlook for key VPP Feedstock

Storage

EV V2G

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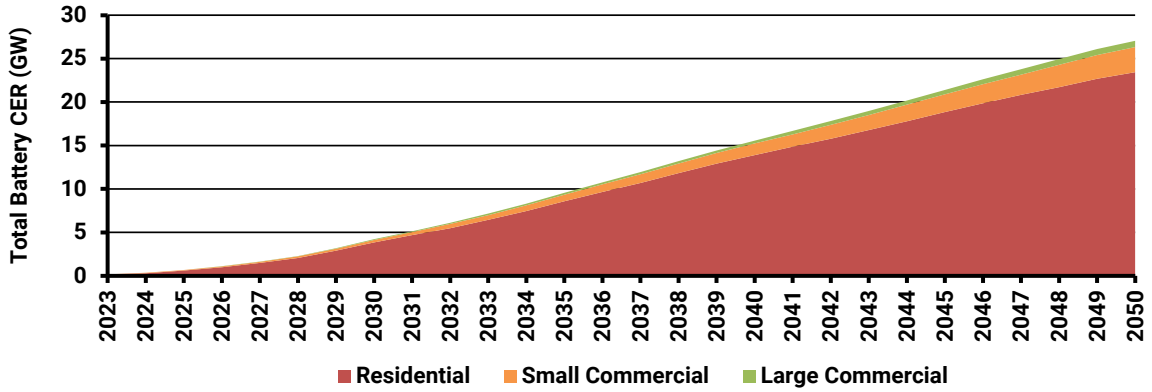
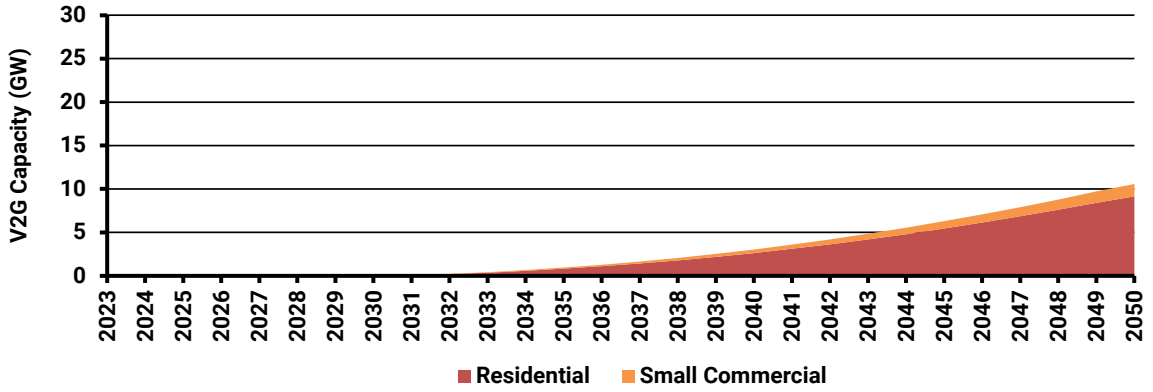
AEMO Outlook for Batteries and V2G VPP Feedstocks

Flexible Battery Capacity (GW) by Customer Class



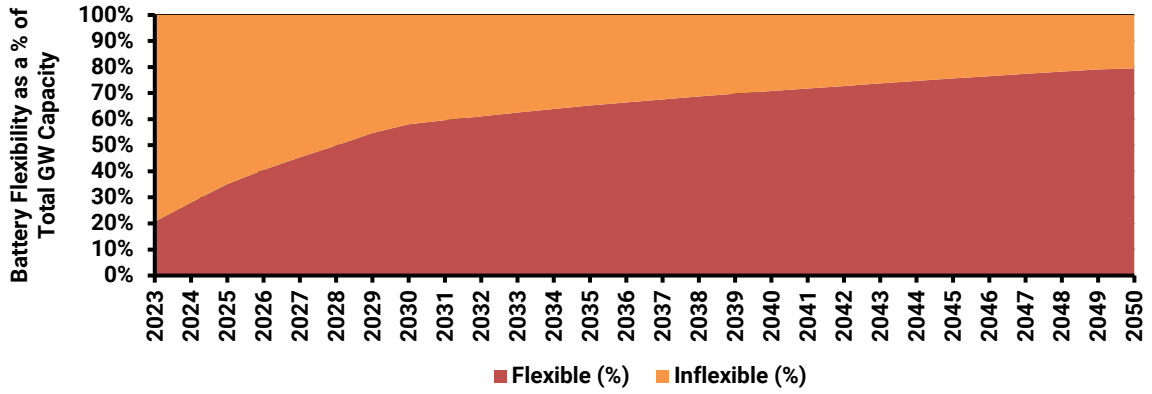
Source: Energeia Modelling, AEMO IASR (2023)

Flexible V2G Capacity (GW) by Customer Class



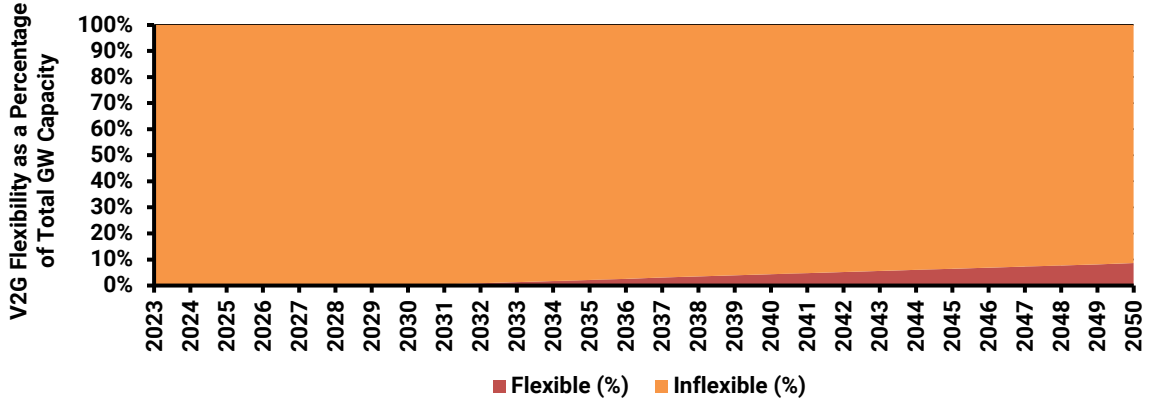
Source: Energeia Modelling, AEMO IASR (2023)
Note: Assumes 5 kW export limit per EV

Flexibility as a Percentage of Total



Source: Energeia Modelling, AEMO IASR (2023)

Flexibility as a Percentage of Total



Source: Energeia Modelling, AEMO IASR (2023), Note: Assumed total GWh capacity of V2G to be 50kWh per vehicle

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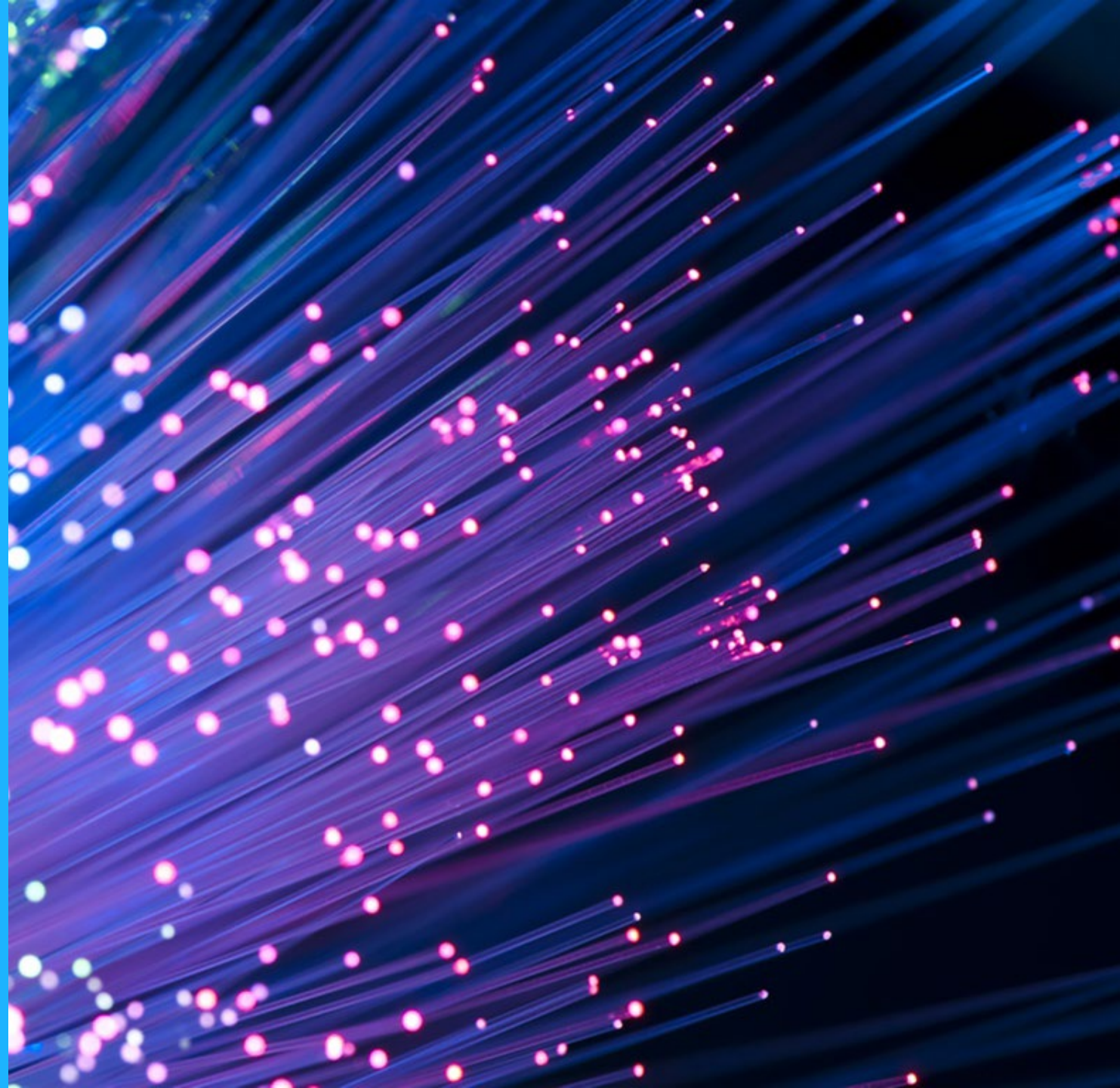
Current Virtual Power Plants

VPP Market Offers

VPP Player Positioning

VPP Economics

VPPs in the FCAS Market



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Summary of Australia's Main Battery VPPs

VPP Feature		AGL "Bring Your Own Battery"	Amber for Batteries	Discover Energy VPP	EnergyAustralia "Solar Optimiser"	Nectr VPP	Origin 'Loop' VPP	Powershop VPP	Arcstream by Qcells	Reposit "No Bill"	ShineHub VPP	Simply Energy VPP	SolarHub / AGL VPP	SonnenConnect	Tesla Energy Plan
Provider	Company	agl	amber	DISCOVER ENERGY	EnergyAustralia	nectr	origin	POWERSHOP	arcstream by qcells	reposit	ShineHub	simply energy	solarhub	sonnen	TESLA ENERGY PLAN
	Primary Function	Energy Retailer	Energy Retailer	Energy Retailer	Energy Retailer	Energy Retailer	Energy Retailer	Energy Retailer	Battery Retailer	CER Retailer	CER Retailer	Energy Retailer	CER Retailer	Battery Retailer	Battery Retailer
	Registered FCAS Load	✓	×	✓	×	×	×	×	×	×	✓	✓	×	✓	✓
Offer Regions	NSW	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	QLD	✓	✓	✓	×	✓	✓	✓	✓	×	✓	✓	×	✓	✓
	SA	✓	✓	✓	×	✓	✓	✓	×	×	✓	✓	×	✓	✓
	VIC	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	×	✓	✓
Sign-up Restrictions	Retail Customer of Provider	✓	✓	✓	✓	✓	✓	✓	✓	×	×	✓	✓	×	✓
	Battery Customer of Provider	×	×	×	×	×	×	×	✓	✓	×	×	×	✓	✓
	BYOB	Optional	✓	✓	✓	Optional	Optional	✓	Optional	×	✓	Optional	Optional	Optional	Optional
	Solar Min Capacity Limits	×	×	×	×	>2MWh Annual Export	>5kW	×	>5kW	×	×	>3kW	×	×	<15kW
	Battery Min Capacity Limits	×	×	×	×	>2MWh Annual Export	×	×	×	×	×	×	×	>4kWh	×
Min Contract Length	Years	5 (Rebate) or 1 (BYOB)	None	None	3	5	None	None	1	7	None	None	None	1	1
Subscription Fees	Annual	×	$228	×	×	×	×	×	$708-$948	×	×	×	×	×	×
Tariffs	Feed-in Structure	-	ToU	ToU	ToU	-	-	-	×	×	Flat	-	Block	-	-
	Feed-in Rate	Standard	Wholesale Prices	ToU	ToU	Standard	Standard	Standard	×	×	Standard	Standard	Declining Block	Standard	Standard
	Usage Structure	-	ToU	-	Flat	-	-	-	Flat	×	-	-	-	-	-
	Usage Rate	Standard	Wholesale Prices + Network Charge	Standard	Standard	Standard	Standard	Standard	Standard	×	Standard	Standard	Standard	Standard	Standard

Source: Energeia Research, Note: Standard tariff means the customer is not moved onto a specific tariff structure

- Companies are setting up Virtual Power Plants to offer a **better than retail bill savings** outcome for consumers
  - Retailer VPPs require being the retailer, but a few, like Sonnen, Reposit, ShineHub do not (SolarHub is partnered with AGL)
  - Battery manufacturers and Reposit require buying their battery, e.g. Qcells, Reposit, Sonnen, and Tesla, with some limits on sizing
  - Terms range from month to month (M2M) to 7 years, with M2M or 1 year being the most common

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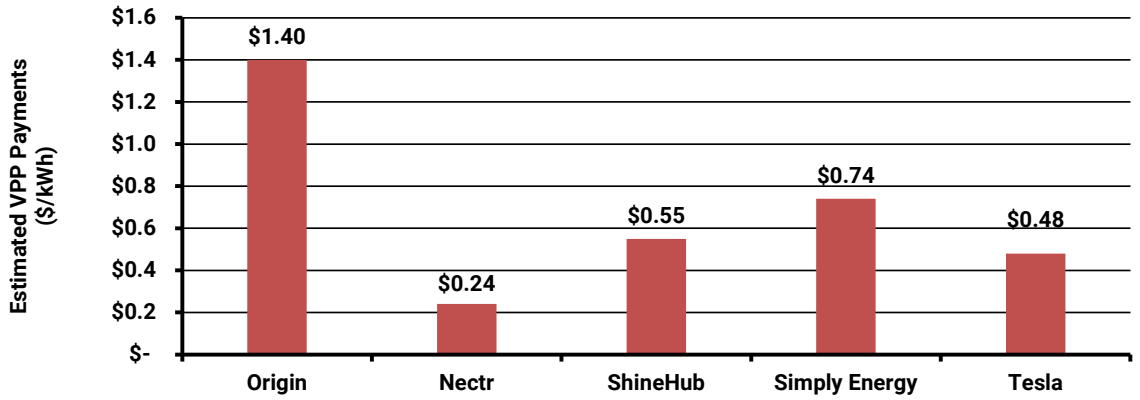
Current Virtual Power Plant Positioning

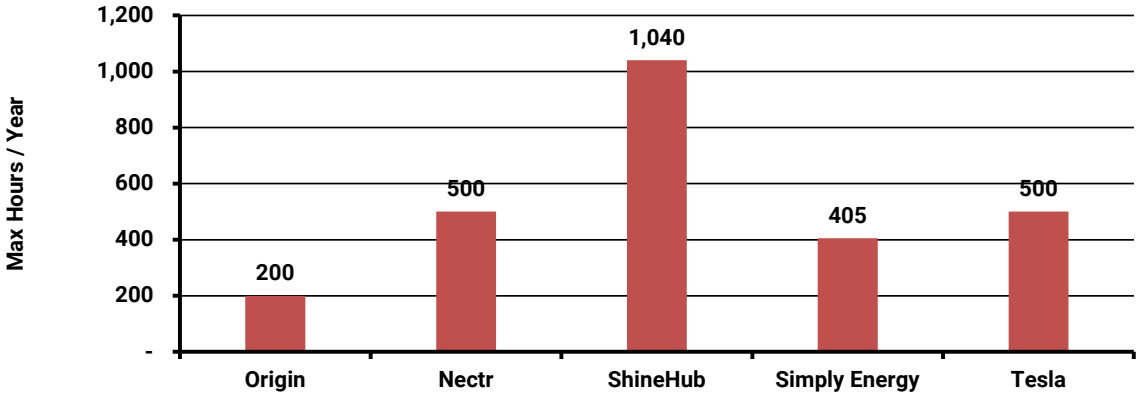
VPP Hours per Year



Source: Energeia Research

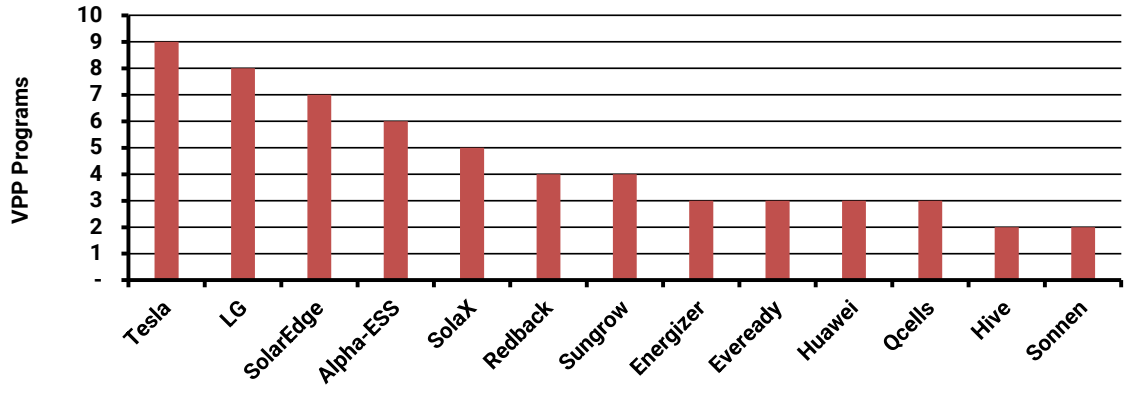
- Australian VPPs taking different positions with respect to hours per year, $/kWh and eligible systems
- Hours per year reflects VPP operator's view of amount of time worth taking control
- Fewer hours will target higher value periods, Origin offers the highest $/kWh for the fewest hours of operation
- No difference in value offered between batteries, generally treated as a commodity

VPP Payments per kWh



Source: Energeia Research

Battery Eligibility



Source: Energeia Research

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Estimated Annual VPP Value by Operator and Service Type

VPP System Benefits – Relative to No Orchestration ($/kWh Battery Capacity)

Benefit Category	Origin	Nectr	ShineHub	Simply Energy	Tesla	Average
Customer Bill (Retail)	-$4.27	-$0.06	-$0.04	-$5.68	-$6.66	**-$3.34**
Wholesale	$34.03	$41.95	-$1.41	$31.27	$31.61	**$27.49**
Contingency FCAS	$0.00	$0.00	$70.50	$39.42	$43.73	**$30.73**
Transmission	-$0.07	-$0.07	-$0.11	-$0.07	-$0.07	**-$0.08**
Distribution	-$0.07	-$0.07	-$0.11	-$0.07	-$0.07	**-$0.08**
System Benefits	**$33.88**	**$41.80**	**$68.86**	**$70.54**	**$75.19**	**$58.06**

Note: Assumed a 10kWh battery, results shown are for a residential customer in SA
Source: Energeia Modelling

- Table shows system (retailer) benefits attainable by value stream compared to "no orchestration", where the battery operates to maximise self-consumption of rooftop solar PV
  - Each VPP's benefit targeting based on our understanding of whether they are FCAS registered, available hours, etc.
- System benefits are maximised by prioritising each day of VPP operation to highest value stream
  - Contingency FCAS available regardless of network or wholesale targeting, it just changes the bidding strategy
- Wholesale and FCAS markets are the source of the majority of system benefits
- Note that the customer's retail bill increased under VPP operation, although not significantly
  - A product of retail pricing not being completely cost-reflective
  - A key communication issue for VPP operators to manage proactively

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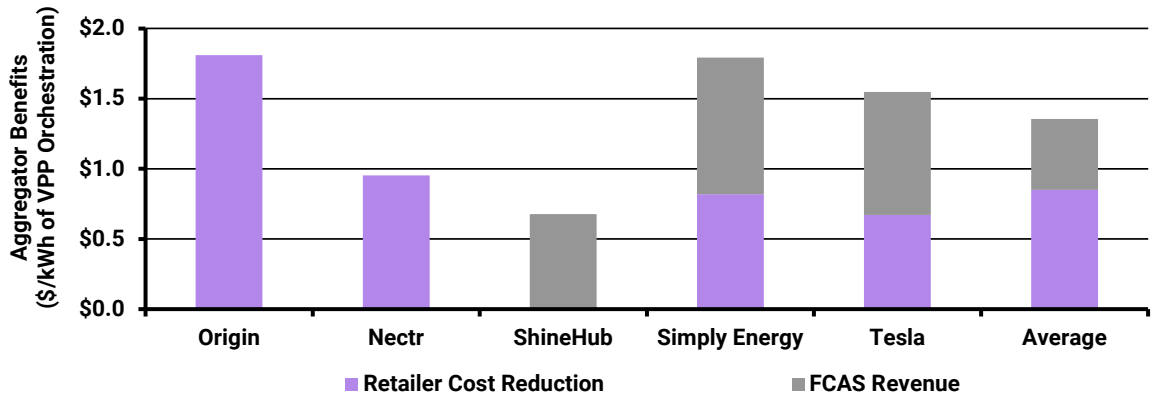
Estimated Virtual Power Plant Economics

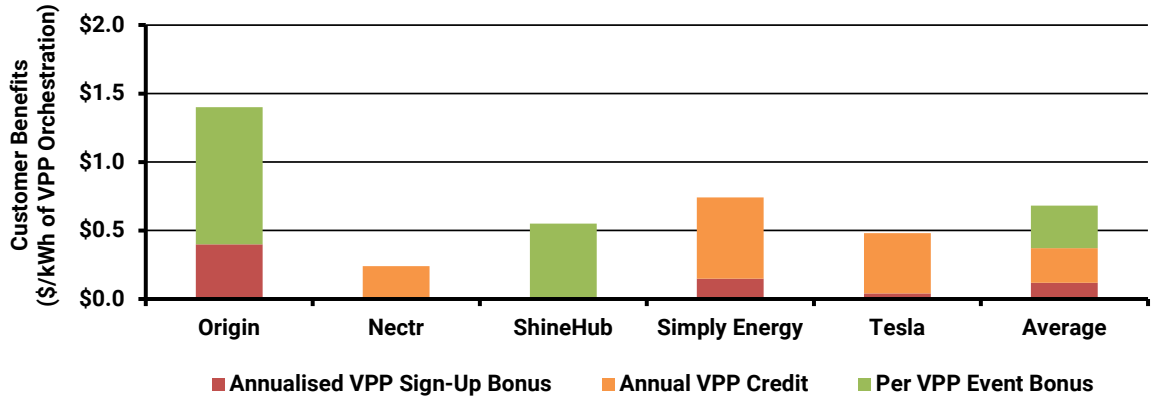
Theoretical Maximum Earnings



Source: Energeia Research

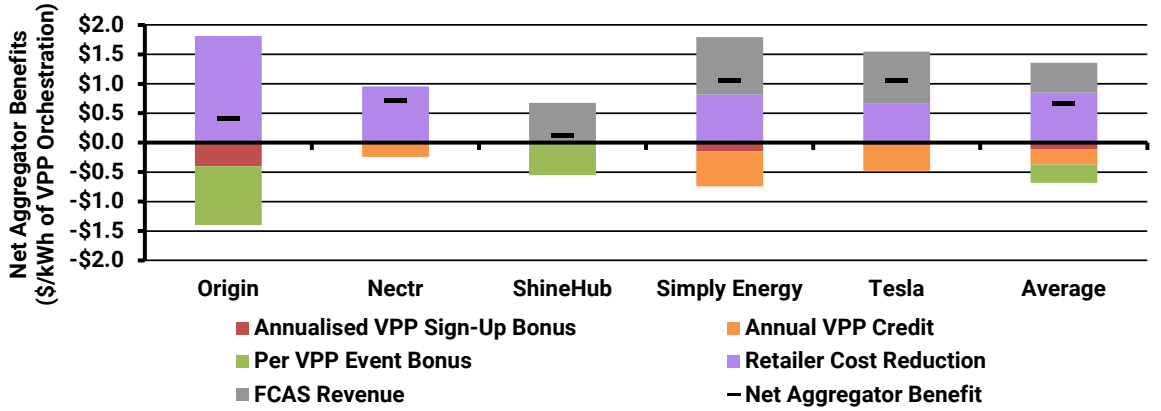
- Analysis assumed perfect information and highest best use strategy implementation
- Note model results are for a residential SA customer, as all selected VPPs are available to this jurisdiction
- Avg. theoretical max earnings are $1.36/kWh, costs are $0.68/kWh, producing $0.68/kWh in net aggregator benefits
- Simply Energy and Tesla's VPP delivered the highest margins, across the retailer cost reduction (wholesale) and FCAS markets
  - Gross profit reflects balancing hours and costs with benefits
  - Higher incentives, e.g. Origin's, likely to attract more VPP resources

Estimated Costs



Note: Upfront payments based on bring your own battery amounts and contract terms
Source: Energeia Research

Gross Margin Estimate



Source: Energeia Research

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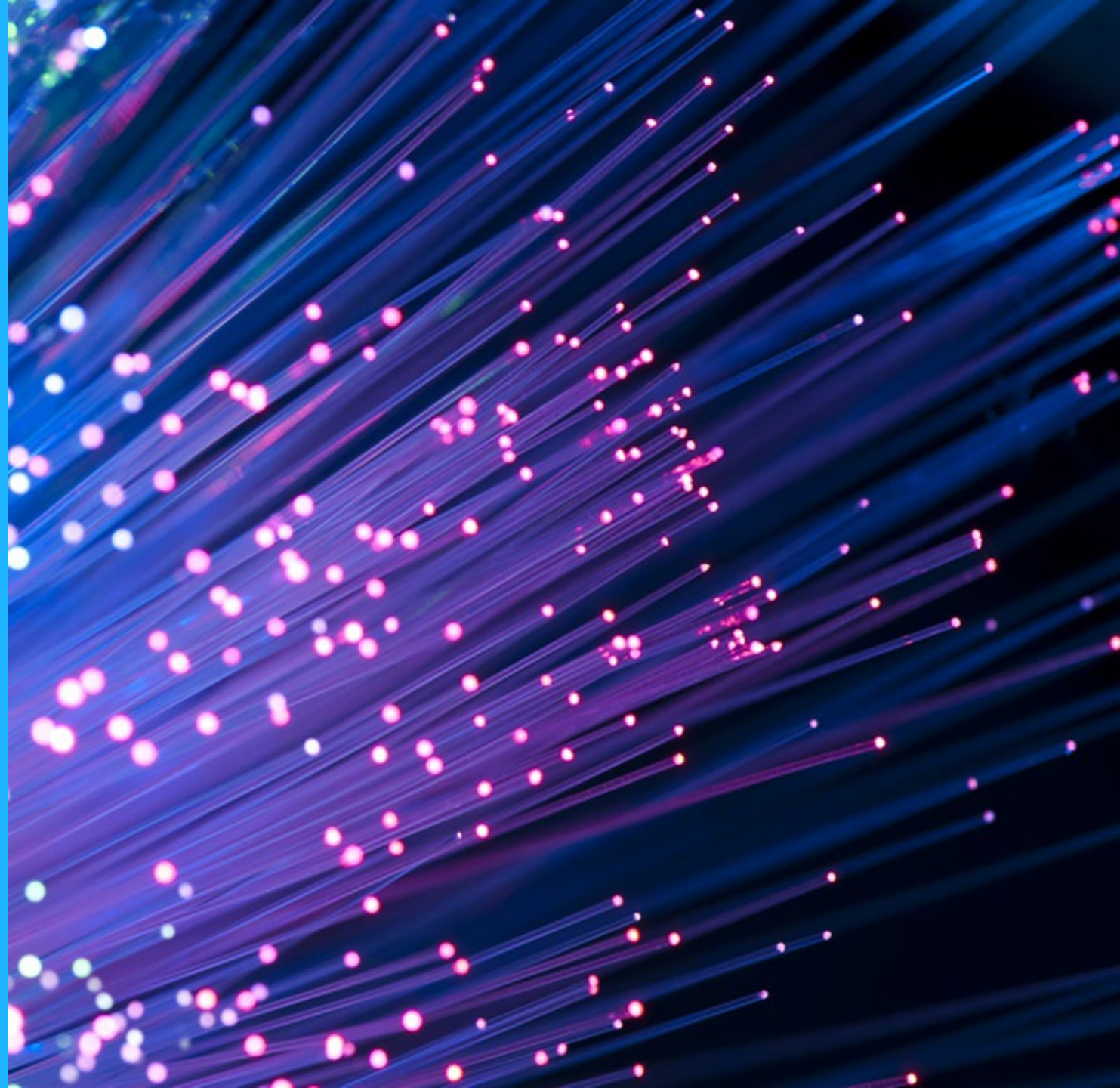
Current VPP Registrations for FCAS

Participant	Station Name	Lower5min (MW)	Lower60sec (MW)	Lower6sec (MW)	Raise5min (MW)	Raise60sec (MW)	Raise6sec (MW)
AGL South Australia Pty Ltd	VPP AGLE SA 1	6	6	-	6	6	-
Discover Energy Pty Ltd	DiscoverEnergy VPPSA	1	1	-	1	1	-
Energy Locals Pty Ltd	Energy Locals SA VPP	12	12	12	12	12	12
Energy Locals Pty Ltd	VPP Energy Locals SA 1	12	12	12	12	12	12
Energy Locals Pty Ltd	VPP Energy Locals NSW 2	1	1	-	1	1	-
Energy Locals Pty Ltd	VPP Energy Locals VIC 2	1	1	-	1	1	-
Hydro-Electric Corporation	VPP HT QLD 1	1	1	-	1	1	-
Shine Hub Pty Ltd	VPP ShinHub SA 1	1	1	1	1	1	1
ENGIE	VPP Simply SA 1	5	5	5	5	5	5
sonnen Australia Pty Limited	VPP sonnen NSW 1	1	1	-	1	1	-
sonnen Australia Pty Limited	AS Sonnen SA	2	2	-	2	2	-

Source: AEMO NEM Registration and Exemption List

- VPP sizes difficult to determine due to lack of reporting
- AEMO frequency control ancillary services (FCAS) markets require reporting of capacity by market type
  - Note that no VPPs are registered in the FCAS regulation markets
- Energy Locals appears to have the largest, and most capable VPP with 26 MW total across the states, with both 12 MW VPPs in SA being registered in all contingency markets
- AGL is the next largest at 6 MW, but is not registered for the 6-second markets
- Simply is the third largest with 5 MW of registered capacity across all contingency markets

Key Takeaways and Recommendations



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Key Takeaways and Recommendations

- **Key Takeaways**
  - Changes in behind-the-meter devices are changing the mix of products and services consumers need and value
  - Feedstock for battery and V2G VPPs substantial to 2050, around 80% of the identified storage resources required in the ISP in GW terms
  - VPPs enable operators to unlock industry benefits and share them with consumers
  - Trend appears to be away from lock-in contracts and towards bring-your-own-device, though incentive structures are mixed
  - Current VPP positioning is wide-ranging, with some consistency in the value paid per kWh, if not the hours reserved
  - VPP terms are key to achieving a profitable VPP operation
  - The lack of market transparency makes it impossible to determine VPP market shares other than from the FCAS market
  - Few VPPs are currently tapping into the FCAS market
- **Key Recommendations**
  - Set hours where they can deliver 80% of industry benefits using 20% of hours
  - Offer a customer bill optimisation service as a value-added extra to win more VPP service contracts with consumers
  - Ensure system and customer optimization is maximizing the value of the resource
  - VPPs that can earn more from consumer assets will earn more profits and/or market share
  - Players that invest in battery VPPs appear set to gain a significant competitive advantage over those investing in utility-scale batteries

Energeia Power Sessions

Q & A

Next Power Session Topic

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Energeia's Power Sessions

- Q&A
  - Add your questions in the chat
  - Unanswered questions will be answered via email
- Vote for your favorite Power Session webinar topic
  - Ancillary Services Market Outlook
  - Best Practice Distribution Grid Resilience Using Microgrids
  - Optimising Gas System Decommissioning
  - Hydrogen Cost Drivers and Least Cost Pathways

Reserve your place at the next **Power Session** discussion

The Balance of Ancillary Storage Pricing

21 May 2024
9:30 AM – 10:00 (AEST)

Where to find Energeia and Ezra Beeman

- Website
  - Energeia.au
  - Energeia-USA.com
- LinkedIn
  - Energeia
  - Energeia USA
- Email
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Watch for a follow-up email with recording and presentation links to share

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Thank You!

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Outlook for key VPP Feedstock

Solar

Storage

EV Charging & V2x

Water Heating

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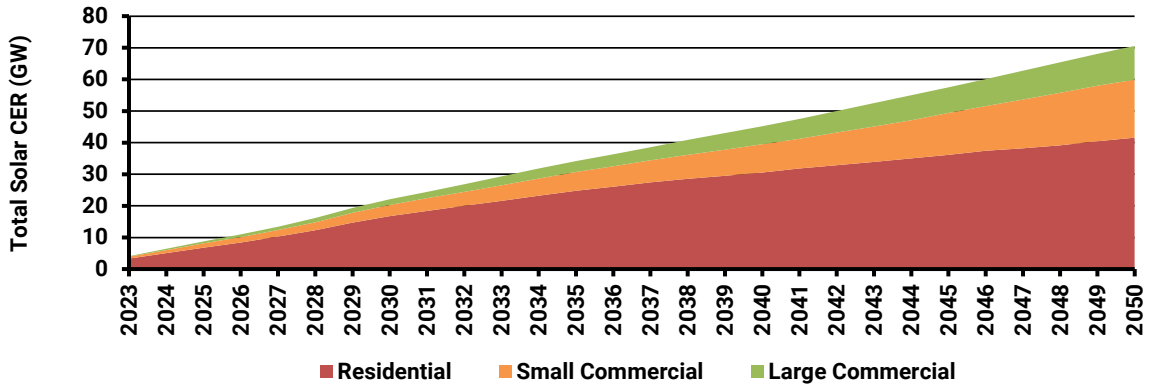
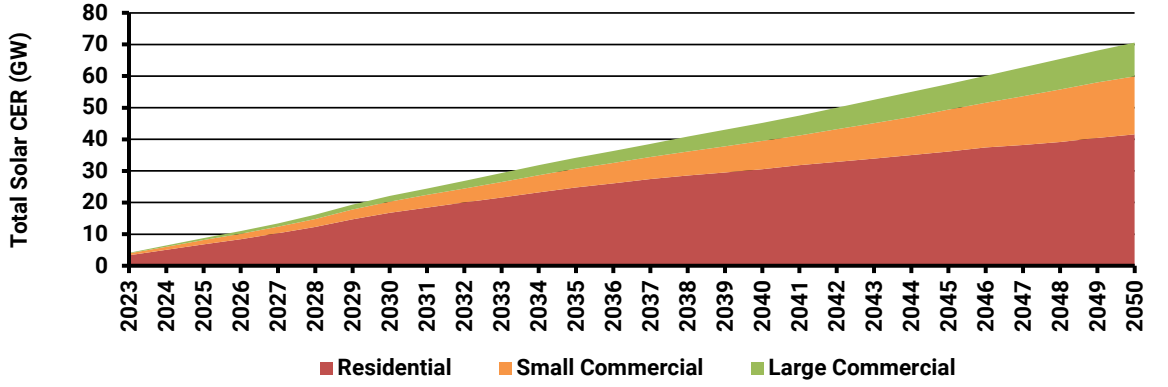
Solar PV

Flexible Capacity by Customer Class



Source: Energeia Modelling, AEMO IASR (2023)

Flexibility as a Percentage of Total



Source: Energeia Modelling, AEMO IASR (2023)

- The following charts show the uptake of flexibility of CER devices
- Forecast uptake of solar is determined from AEMO's most recent Inputs and Assumptions Report (IASR), utilising the Step Change scenario

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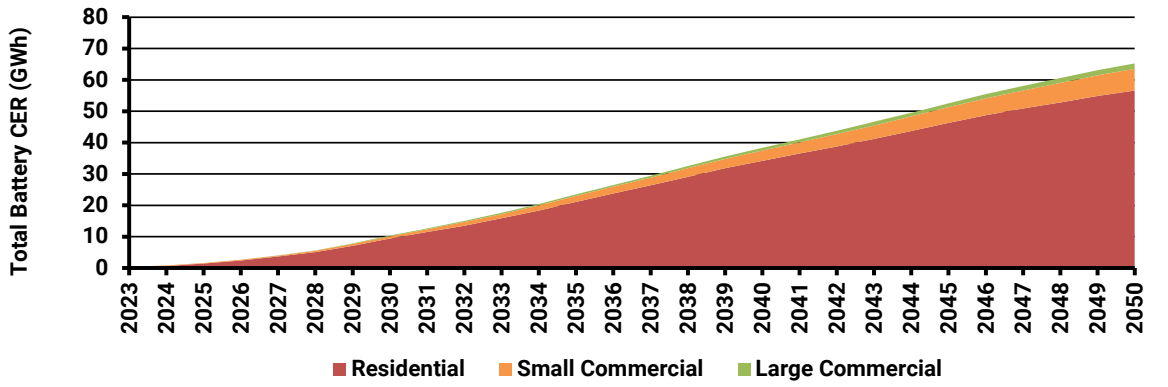
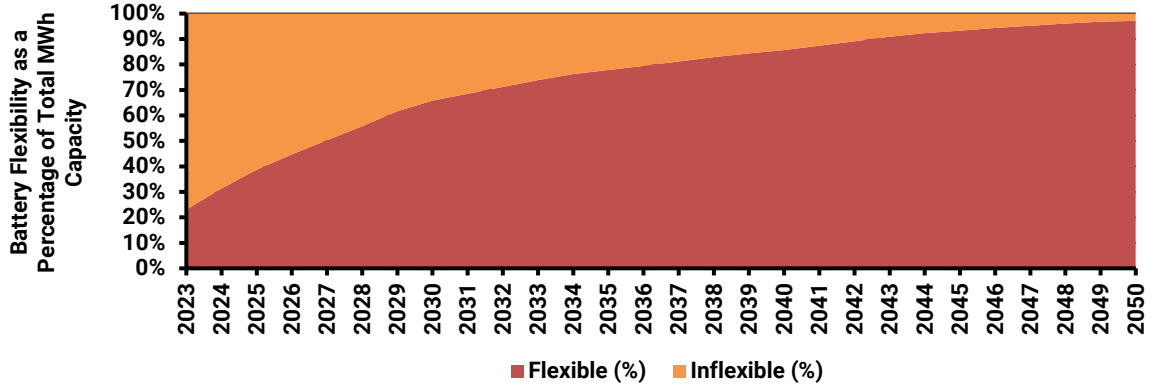
Batteries

Flexible Capacity by Customer Class



Source: Energeia Modelling, AEMO IASR (2023)

Flexibility as a Percentage of Total

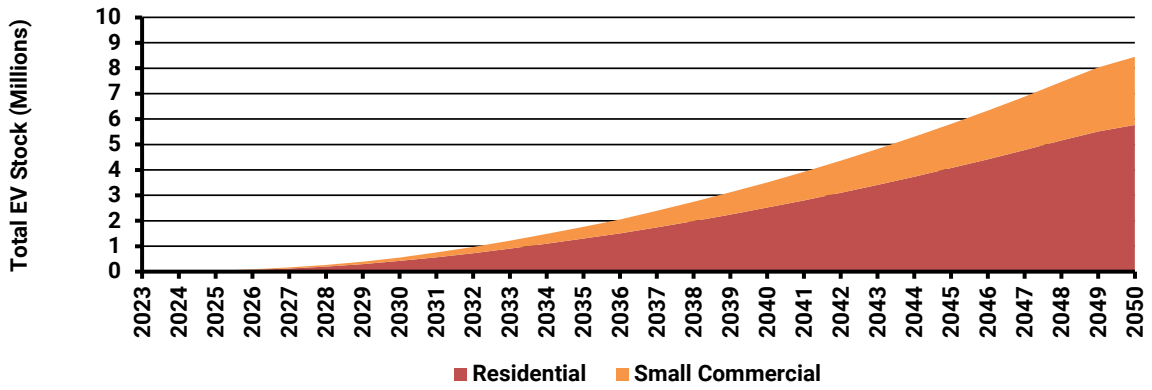


Source: Energeia Modelling, AEMO IASR (2023)

- Battery uptake and aggregated energy storage participation are sourced from AEMO's most recent IASR, utilising the Step Change scenario

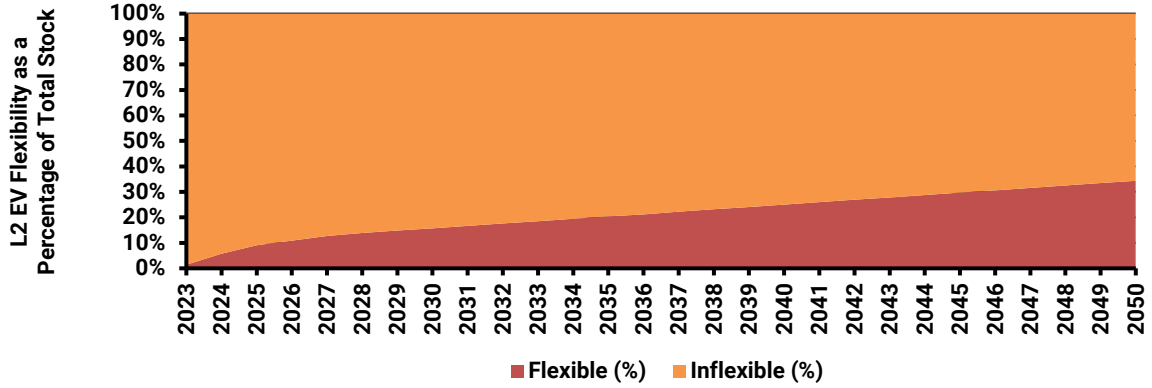
EV L2 Charging

Flexible Capacity by Customer Class



Source: Energeia Modelling, AEMO IASR (2023), E3 (2019)

Flexibility as a Percentage of Total



Source: Energeia Modelling, AEMO IASR (2023), E3 (2019)

- The charts show the level of flexible CER capacity for L2 EV charging in the NEM, in number of vehicles
- Uptake of vehicle stock are developed by CSIRO and GEM for the AEMO's 2023 IASR
- The participation rate of smart charging through controllable devices is as forecast by E3 for the federal government for the Regulatory Impact Statement (RIS) for Demand Response Capabilities of Devices and Appliances

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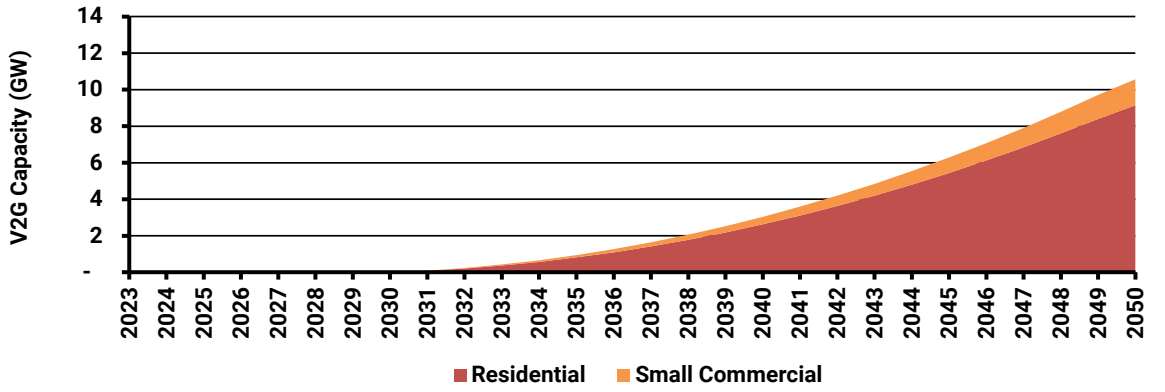
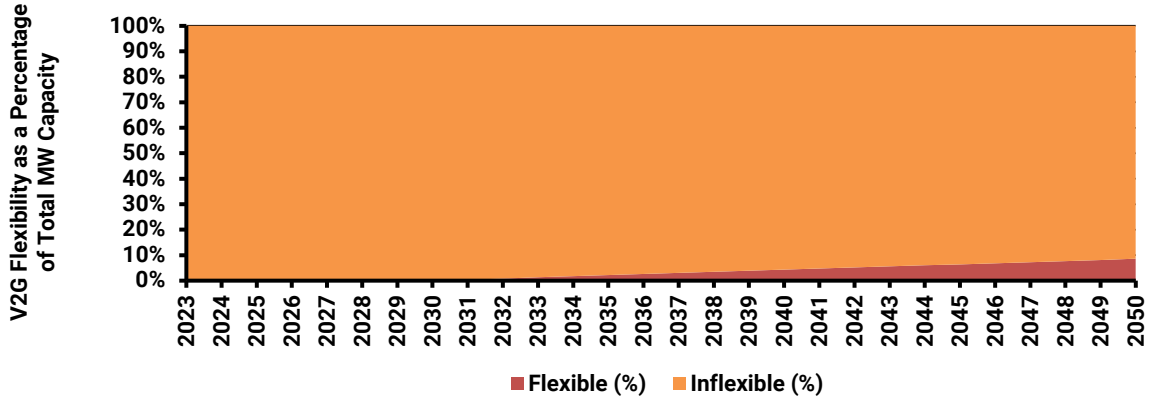
EV V2G

Flexible Capacity by Customer Class



Note: Assumes 5kW Export Limit Per EV
Source: AEMO IASR (2023), Energeia Modelling

Flexibility as a Percentage of Total

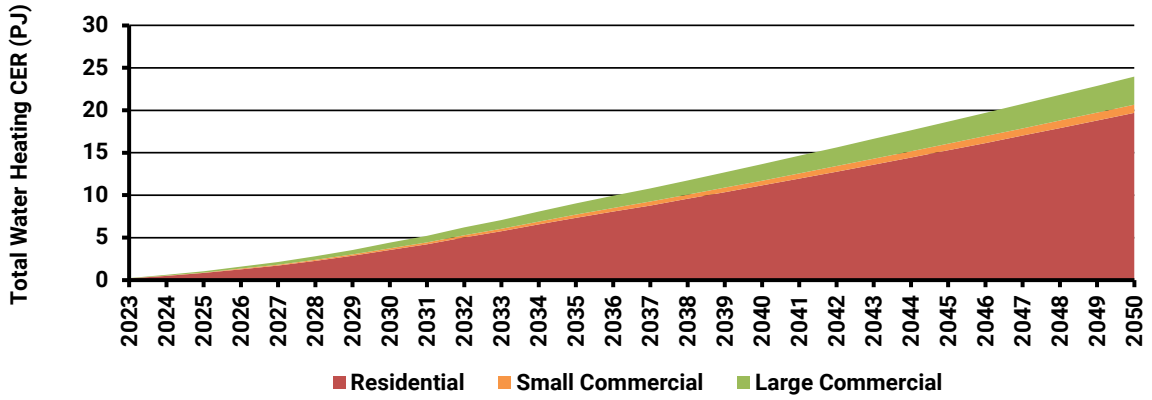


Source: AEMO IASR (2023), Energeia Modelling

- V2G Capacity sourced from AEMO's most recent IASR, utilising the Step Change scenario
- Residential vs. Commercial participation split pro-rata based on EV uptake

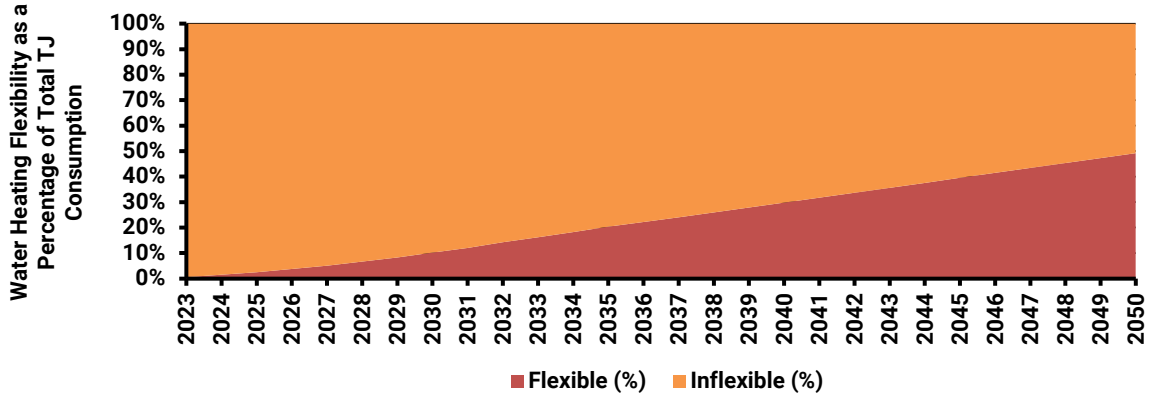
Water Heating

Flexible Capacity by Customer Class



Source: Residential Baseline Study (2022), Commercial Baseline Study, E3 (2019)

Flexibility as a Percentage of Total



Source: Residential Baseline Study (2022), Commercial Baseline Study, E3 (2019)

- The charts show the level of flexible CER capacity for water heating in the NEM
- Water heating appliance stock forecasts are sourced from the
  - Residential Baseline Study for residential uptake
  - Commercial Baseline Study for commercial uptake
- The participation rate of smart appliances in demand response increases over time, as forecast by E3 for the federal government RIS

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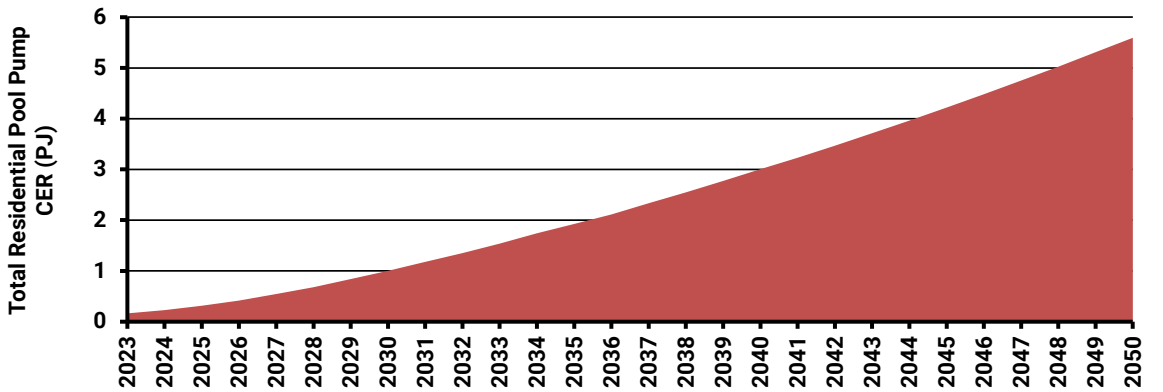
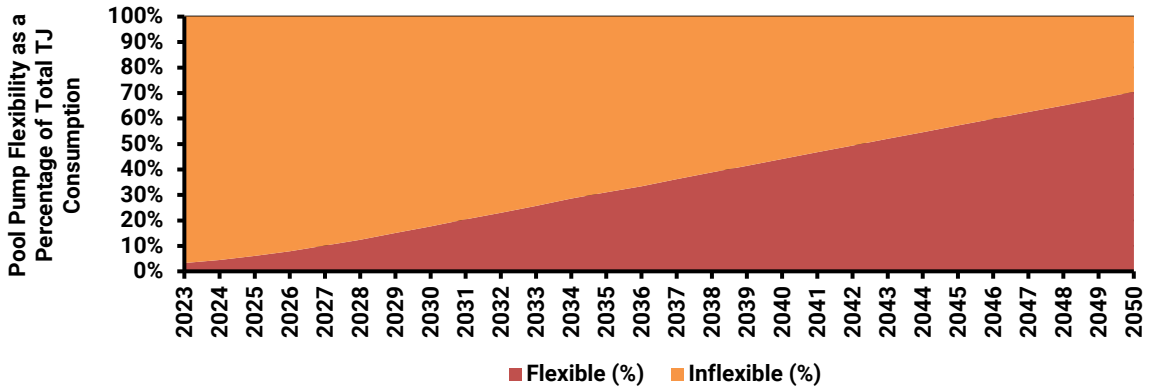
Pool Pumps

Flexible Capacity by Customer Class



Source: Residential Baseline Study, CSIRO, E3 (2019)

Flexibility as a Percentage of Total



Source: Residential Baseline Study, CSIRO, E3 (2019)

- Residential pool pumps are additionally sourced from the Residential Baseline Study, utilising E3's forecast trends in controllable installations
- Pool pumps exhibit a strong year-on-year growth in level of flexible uptake

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