The Marginal Economic Benefits of Centrally Controlled and Maintained Virtual Power Plants

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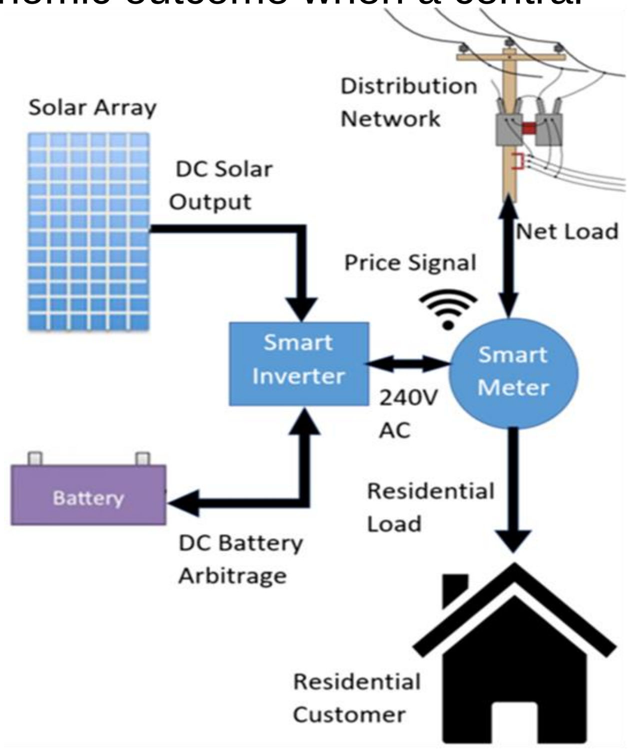
Introduction

Virtual power plants (VPPs) are expected to be integral components of nascent, intelligent, large-scale electricity systems, enabling the integration of distributed energy resources (DERs) to form a coalition to trade in wholesale markets, maximize profits and stabilize grids. This investigation develops a new, internationally replicable model to estimate the economic outcome when a central body owns, deploys, co-ordinates and maintains DERs in a market.

Australia's National Electricity Market (NEM) is used as a case study to analyze the marginal economic benefit a body receives when many DER systems (i.e. solar arrays, batteries, smart inverters and smart meters) are deployed across multiple locations within the NEM.



One DER system

Aim

Develop an internationally replicable model to estimate the economic outcome when a central body (e.g. electricity retailer, community organization or utility) owns, deploys, co-ordinates and maintains DERs in a market.

Datasets accounted for and their sources

Dataset	Source
Capital costs	CSIRO
Maintenance costs	CSIRO
Installation costs	CSIRO
Load profiles	AEMO
Irradiance profiles	BOM
Wholesale price profiles	AEMO
Wholesale price projections	AEMC
Transmission network tariffs	AEMC
Distribution network tariffs	AEMC
Network tariff projections	NA*
Daily average residential loads	AEMC
Annual average load projections	AEMO

* Assumed constant due to legislative uncertainty (AER)

Method

This analysis evaluated DER systems of the following solar array sizes: 2.5kW, 3kW, 3.5kW, 4kW, 4.5kW, 5kW, 7.5kW, 10kW, 15kW and 20kW. The analysis was applied to ten locations in the NEM.

A. Assumptions

Two key simplifying assumptions were made:

1. Battery sizes and inverter limits for each system will be determined by array size.
2. DER system lifetime matches the expected warranty of the subcomponents.

This meant that while array and inverter sizes were constant in each location, battery size fluctuated according to the maximum energy storage requirement. Battery sizes for one location are shown below.

PV and Inverter Size (kW)	Storage Requirement (kWh)	Battery (kWh)
2.5	7.7	8
3	10.5	11
3.5	13.5	14
4	16.5	17
4.5	19.5	20
5	22.5	23
7.5	37.0	38
10	53.5	54
15	84.9	85
20	116.2	117

Assumed Battery Sizes for Canberra

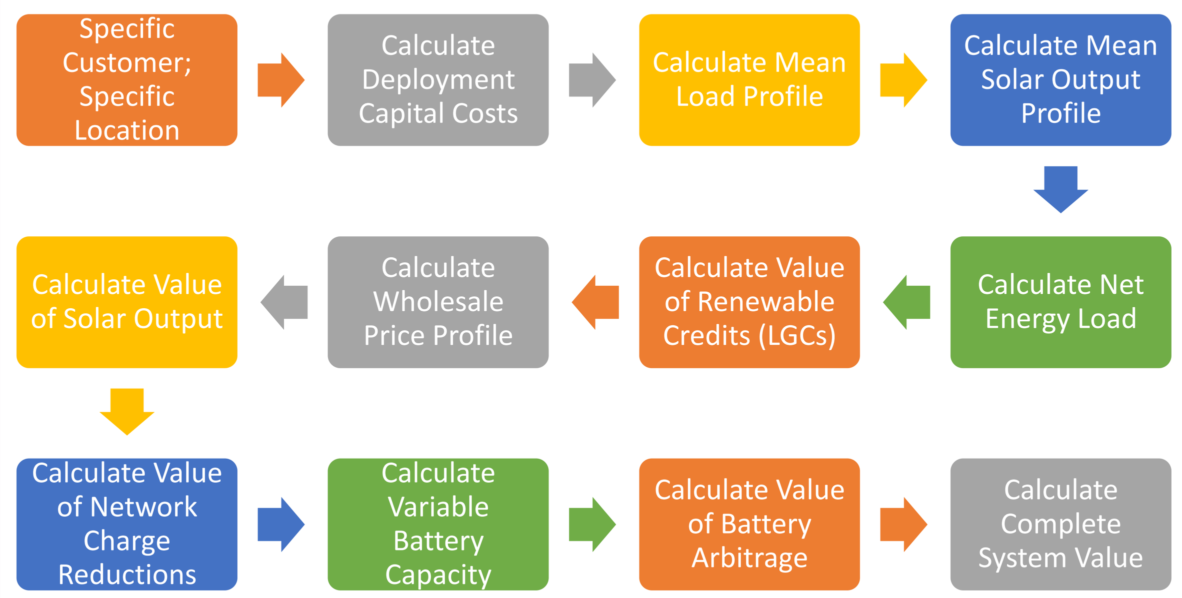
Therefore, this analysis used the following assumptions.

System Component	Assumption
Solar array size	1.5kW – 20kW
Inverter size	1.5kW – 20kW
Battery size	Net energy surplus storage requirement
Battery charge/discharge time	30mins (one interval)
Solar derating factor	0.85 [27, 28]
Battery round-trip efficiency	0.90 [20]
Battery depth of discharge (DoD)	0.9 [20]
DER system warranty	10 years [20]
DER system life	10 years (warranty)
LGC price (Sep 2017)	$82.30/MWh
Yearly maintenance cost	$60 per annum [20]
Installation cost	$400 for <7kWh: function of kWh for >7kWh [20]
Daily average residential load	Regional: 0.460kW – 0.979kW [29]

DER system assumptions

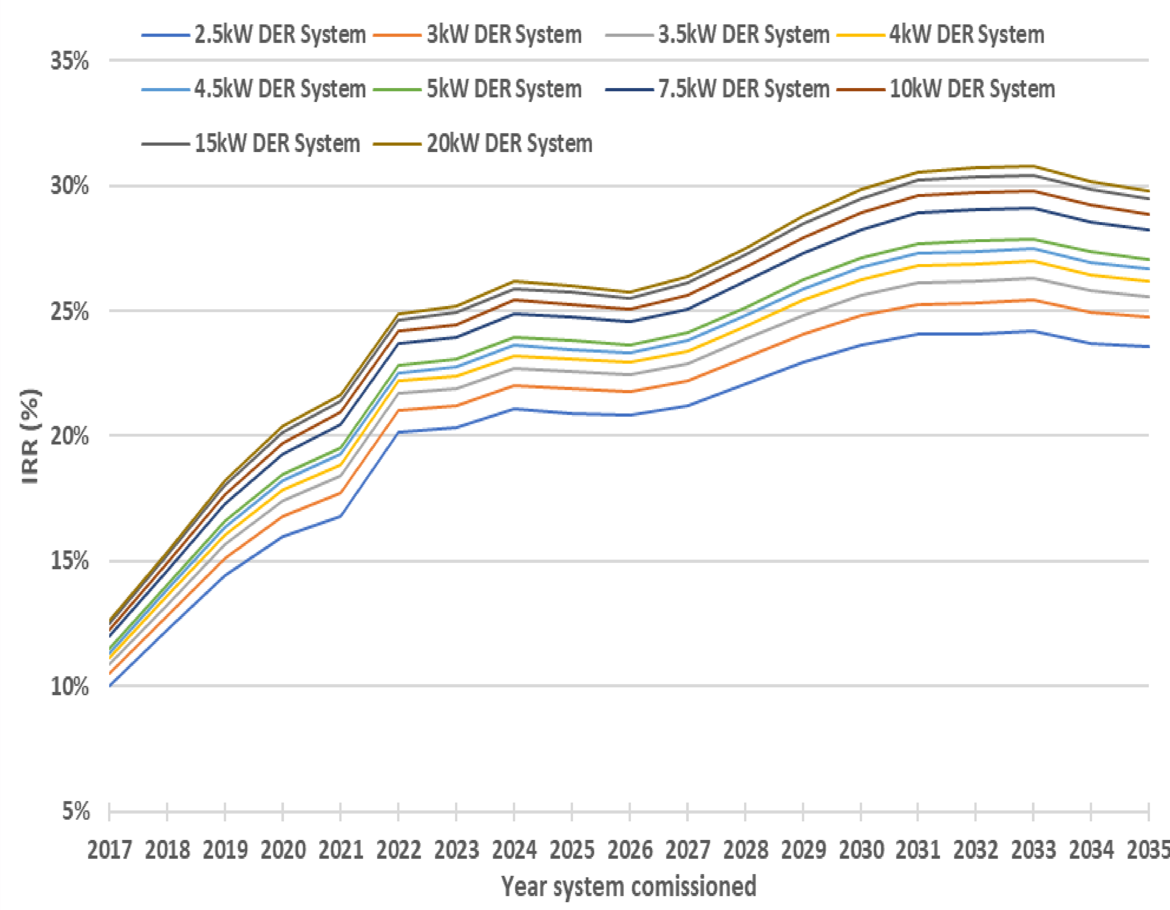
B. Procedure

The analysis followed the procedure illustrated below.



Results

The IRR of DER systems commissioned in each location every year from 2017 to 2035 were calculated. For each location, IRR and payback period follow consistent trends. Specifically IRR increases with system size to a limit and IRR tends to increase with year commissioned. These trends are illustrated in the Canberra IRR analysis.



Canberra IRR Analysis

Thus, it makes sense to simplify results by comparing representative systems from each location.

IRR results between locations for 5kW systems were compared. The ranked locations on a yearly basis are shown below.

Location	2017 IRR (%)	2035 IRR (%)	Avg. IRR (%)
Longreach	16.7	33.9	28.9
Townsville	15.7	32.3	27.5
Brisbane	13.9	28.7	26.1
Adelaide	17.4	28.7	25.5
Bourke	12.5	28.2	24.1
Canberra	11.5	27.1	23.1
Wagga Wagga	11.0	25.8	21.9
Sydney	11.0	25.6	21.8
Melbourne	3.3	13.1	8.9
Hobart	-2.3	5.1	2.2

IRR Results for a Representative 5kW Array System

Thus, this investigation conservatively calculates that a central body in the Australian NEM coordinating a VPP could expect to receive a sustained marginal economic benefit of greater than 20% return on investment for eight of the ten locations analyzed, beating industry benchmarks for DNSPs and electricity retailers.

These results support the commercial viability of centrally controlled and maintained VPPs in Australia.

Conclusion

This investigation has successfully provided a novel, globally replicable framework to estimate the expected economic benefit of centrally operated VPPs for a specific geography or customer type in an accessible means.

Furthermore, it demonstrates that in the Australian market VPPs have significant commercial potential.

It is the authors' hope that by making it easier for decision-makers to develop economic appraisals of VPPs, this paper contributes to progressing adoption, and accelerates the transition to a renewable energy future.

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