Curtin University

Increasing the uptake of solar PV and battery storage in strata residential developments

Final public report, January 2021

Make tomorrow better.

curtin.edu.au

Increasing the uptake of solar PV and battery storage in strata residential developments

Acknowledgements

This Project received funding from the Australian Renewable Energy Agency (ARENA) as part of ARENA's Research and Development 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.

Project Partners

Appreciation to the following partners who have had valuable input into this research through contribution of cash or in-kind.

ARENA, Curtin University, CRC for Low Carbon Living, Landcorp (DevelopmentWA), Solar Balance, Synergy, Western Power.

The following partners are acknowledged for their knowledge and collaboration:

Access Housing, the City of Fremantle, Yolk.

Report preparation and contact

Jane Loveday and Gregory Morrison

Paula Hansen, Moiz Syed, James Eggleston and Jessica Breadsell

Curtin University Sustainability Policy Institute

Date of this report: 14 January 2021

Contact: Professor Greg Morrison (greg.morrison@curtin.edu.au)

Executive Summary

Curtin University Sustainability Policy Institute (CUSP) is pleased to present this report on the research project "*Increasing the uptake of solar PV and battery storage in strata residential developments.*" This research is based on a case study of three medium density residential developments in the White Gum Valley precinct, located in the City of Fremantle, Western Australia.

The success of rooftop household solar photovoltaic (PV) installation in Australia is well documented. This success has not extended to increased uptake for strata residential developments due to ill-defined rules around shared ownership, and a lack of demonstration projects in Australia. Four key objectives were defined:

1. Identify key factors impacting on market uptake for solar PV and storage solutions within a medium-scale urban strata development.
2. Develop a governance model and microgrid design for operating solar PV, battery storage and metering solutions for medium-density strata title urban developments.
3. Investigate costs, benefits and risks of the identified governance model from the perspective of all affected stakeholders.
4. Study the network implications for the mainstream deployment of solar with energy storage in a medium density development.

Further to these objectives, this report presents:

- The performance and usage of the shared solar PV and battery energy storage;
- The experiences of stakeholders; and
- Recommendations for future work.

Key Findings

Objective 1 (factors impacting on uptake of PV and storage):

- Due to the Strata Titles Act, a split incentive occurs in the deployment of solar PV and battery storage for strata developments, as the developers who would be responsible for infrastructure costs, would not benefit from the reduced energy costs. The longer payback period for PV and battery storage may discourage the Body Corporate from using sinking funds for this investment.

- The National Energy Market (NEM) regulatory regime does not present any barriers to the proposed governance model. At present, residents can share on-site behind the meter, but are prohibited from sharing through the network, however there have been some developments that indicate this restriction will fall away.
- The main physical issue constraining the installation of solar PV in strata developments is the roof space available for the number of panels required to cover the energy needs of the residents. Building height is another consideration as installation costs increase with height.
- From the 2016 ABS data, 24.2% of the Australian housing stock could be classified as medium density (< four storeys) and thus suitable for installation of solar PV and battery storage.

Objective 2 (governance model and microgrid design for solar PV and storage):

Strata Utility Governance Framework Summary

- Shared battery and solar system
- The strata management body manages the system as common property
- Can be used in built strata, survey strata and community title
- Meets up to 80% of resident's electricity needs

- The framework for the governance model structure includes the flows of commercial values, the engineering modelling and installation of the microgrid, as well as the legal and regulatory requirements of the system. Policy and regulatory reform can make renewables adoption easier and eliminate other institutional, financial, and technological obstacles.
- Implementation of the governance model requires all of the stakeholders in this sector, not limited to industry stakeholders, local communities, policy makers, or customers, participating in adopting a more feasible, sustainable, cost saving, and innovative energy renewables structure in the future.
- The engineering structure relies on extensive system modelling for the design of the solar PV and batteries, installation of bi-directional meters, data logging, communications, and database management, maintenance and visualisation.
- Solar PV modules size at WGV sites were: Gen Y 9 kWp, Evermore 54 kWp and SHAC 19.6 kWp respectively. Gen Y and Evermore employed an AC coupled

configuration whilst SHAC used a DC coupled system. Hence in the AC coupled configuration, the solar PV supply power to the residential loads as well as charge the batteries. In the DC coupled configuration at SHAC, the batteries are being charged by incoming Solar PV generation and then the loads are supplied power through an inverter.

- Lithium iron phosphate batteries with a standard battery warranty of 5 years were installed. The Powercore contains the battery energy storage system (BESS) which consists of the power flow hardware (Inverter and DC-DC converters) plus the battery management system, which controls the flow of energy and the state of charge of the battery
- Dashboards delivered a pictorial illustration of real-time and historical meter data congregated at defined time intervals. Each tenant has an individual apartment monitoring page as well as an overview page where energy/water consumption total, energy export/import and carbon footprint information are included.

Title (Developer)	Gen Y (Landcorp)	SHAC (Access Housing)	Evermore (Yolk)
Dwellings	3	12 + 2 shared studios	24
PV (kW)	9	19.6	53.6
Battery (kWh)	10	40	150

- Residents pay their electricity bills to the strata management, with energy from the grid charged at a lower rate than charged by the state owned retailer. The P2P (peer-to-peer) platform is used to enable electricity trading between prosumers and consumers. A blockchain billing system is used to allocate the renewable energy fairly, with the margin earned used to offset the levies on the strata

Objective 3 (governance model costs, benefits and risks):

- Quoted costs for both capital and operational expenditure were not always the same as final costs due to the novel nature of this project.
- The Net Present Value (NPV) of Gen Y is positive, however NPV of both Evermore and SHAC are negative and would not have been a good use of capital at the time of design (2015). Financial viability of battery technology only came about in the year

2016[1]. Along with the inclusion of avoided costs due to electricity savings, the technology of integrated battery/solar has since become commercially viable.

- The governance model was found to be viable in Australia based on Jackson McDonald's and McCullough Robertson's legal analysis of commercial, strata and electricity regulation issues.
- The Australian Taxation Office has provided general guidance regarding tax implications of implementing the governance model for three different ownership scenarios.

Objective 4 (network implications for large scale deployment):

- Interconnected local energy markets have emerged as an anticipated outcome of a large scale shift in the electricity industry away from centralised network planning.
- Network effects are present in the accelerated uptake of DER and have the potential to transform legacy electricity networks into prosumer owned economic engines.
- Policy implications of this study demonstrate the benefits of unbundled network costs for sharing DER on utility networks to fully realise the true value and utility of DER in practical terms.

Case study performance:

Market Acceptance of the WGV Project

- The overall living experience among residents appears positive and the concept of solar-battery infrastructure is understood at a high level.
- Sustainability is important to residents and therefore the shared solar-battery system is an attractive point of difference when purchasing a property.
- The technical requirements and Australian Standards for grid-connection of battery systems are extremely prescriptive, and the process for certifying battery systems that are not already covered by Australian Standards requires considerable time and effort.

Energy Performance

- The daily energy demand of the average apartment unit is 57% lower than the benchmark for a typical Perth apartment. On average the yearly grid imported

[1] Technology Forward Curve - https://arena.gov.au/assets/2016/04/ESCRI-General-Project-Report-Phase-1.pdf#page=69

electricity from the three sites was 40% of the demand whilst renewables provided 60% of the energy demand.

- The self-sufficiency rates from the three developments could be improved by optimising the systems through better control of PV exports (particularly at Gen Y and Evermore) and through use of the battery only during periods of higher consumption. On a larger scale, this could assist in smoothing the evening peak demand, thus also benefitting the utility network. Future research could examine how day ahead forecasting could be used to further optimise the systems.
- The renewable system at SHAC was undersized when taking into consideration the size of households and occupancy behaviour. Most of the artists stayed at home more than those in a typical household, so daytime electricity use was higher. Hence, the SHAC microgrid was more reliant on grid imports when compared with the other two sites.

Home System of Practices

- Heating and cooling practices consume the largest proportion of household energy, and it was found that household energy use decreases due to technology and design influences.

Energy Sharing

- Energy trading via platforms behind the meter has the potential to create financial value for residents. However, in practice, there have been teething problems with the complexity of implementing the system and there has been insufficient data to confirm value as yet.

Experiences of stakeholders:

- The interviews revealed a considerable degree of divergence between stakeholders' levels of understanding and knowledge of the system design, roles, and project progress.
- Beliefs and opinions regarding system functioning varied greatly. Participating organisations were knowledgeable with regards to their own specific role but generally had little information regarding the particularities of other stakeholders' activities.
- Communication is key — between partner organisations, and partners and residents.

- While having an understanding of the system at a higher systems level the residents generally had a poor understanding of how their solar and battery storage systems actually worked, which was linked to a lack of information being available to them.
- Prominent motivations for residents to move to WGV were a general interest in sustainable living/reducing their carbon footprint, and a sense of community living.
- The trialled set-up for energy sharing led to the need for an additional role, namely that of data monitor; given the novelty of the trial, stakeholders were initially unaware of the need for such a role; this needs to be explicitly accounted for in future projects.
- One developer stated they have achieved experience and learning from the project. They believe they have reduced CO_2 emissions from energy use and provided market sector learning.
- Another developer indicated the ARENA funding permitted them to test the market and see if there was demand for this in the industry.
- Both Access Housing and Yolk expressed frustration at the slow approval process for the solar PV and battery systems, as well as the need for improved communication to raise awareness of how the benefits of the systems can be maximised. Despite this, both companies are broadly supportive of the technologies and accept the trading system as a concept to be further explored in future projects.
- Solar Balance have used project to develop a range of technical solutions (e.g. microgrid platform) and successfully navigated approval processes by Western Power. However, costs were higher than expected.
- In the view of residents, trials such as this are crucial in promoting an accelerated uptake of renewable sources of energy. Overall living experience is positive. While the solar PV and battery storage systems were not necessarily the primary driver for residents taking up occupancy at WGV, residents considered the sustainability feature to be a plus and that the solar-battery system was a factor in their decision to purchase.

Key Lessons Learned

- More detailed training and education on the workings of the financial settlement system is required for the parties who will be administering the energy trading/billing systems (strata managers).

- Strategic communications and a targeted education program are required to raise awareness among residents of the benefits and application of the solar-battery systems and associated trading platforms.
- While sustainability is a driver, the commerciality of the systems is of greater interest to most stakeholders. More should be done to demonstrate the economics of solar-battery solutions and enable all parties to better understand how the systems can be commercially viable in the future.
- Market acceptance is generally good, however, more detailed longer-term studies are required in order to generate more meaningful and practicable learnings for future projects.
- Technical specifications and compliance with Australian Standards (specifically AS 4777) are significant hurdles that must be factored into future solar-battery developments.
- Data flow and acquisition are critical factors in these innovative projects and should be prioritised, with interruptions minimised.
- Communication was vital for coordinating technical experts across the industry and synchronising with the network operator, when compliance issues surfaced.
- It is essential that the project planning phase includes all stakeholders and partner organisations.
- Involving the beneficiaries is crucial in future planning and implementation of shared renewable energy systems.
- Digital technology in particular may lead to unexpected complexities and consequences that reduce the effectiveness of shared energy governance systems.
- The personal practice history of residents influences energy consumption. Changes to the meaning element of personal hygiene practices show how these are interlocked and unlikely to change in their duration and timing when there are other demanding practices to be undertaken (Breadsell, Byrne, & Morrison, 2019a)
- The self-sufficiency rates from the three developments could be improved by optimising the systems through better control of PV exports (particularly at Gen Y and Evermore) and through use of the battery only during periods of higher consumption. On a larger scale, this could assist in smoothing the evening peak demand, thus also benefitting the utility network. Future research could examine how day ahead forecasting could be used to further optimise the systems.

Recommendations

- To support the deployment of the governance model Australia-wide, further work has to be done in other states and territories particularly around community titling and rulings in relation to embedded network operators.
- It is recommended that the commissioning phase of any future projects involves hands-on training with strata managers (or whichever party will be administering electricity billing/trading) for at least one complete billing cycle.
- It is recommended a detailed timeline of education and engagement activities, with key milestones, be developed for residents, strata managers and any other interested parties involved in similar shared solar-battery projects.
- It would be beneficial to include a two-way feedback loop to enable residents and administrators to share learnings and take greater ownership of the financial settlement models and sharing systems.
- Future shared solar-battery projects should be supported by a structured and comprehensive engagement and education program for strata managers, tenants and homeowners, which should include frequent touch points for the duration of the project.
- Where possible, all hardware (PV systems, inverters and batteries) should be sourced from an equipment list pre-certified by Australian Standards, the network operator, and the relevant regulatory bodies. Where non-certified hardware is required, additional time should be factored into the program to accommodate the certification process.
- Further investigation is required in quantifying the benefits of deploying behind the meter generation and storage on the provision of network infrastructure. Specifically, its effects on 'Design After Diversity Maximum Demand' (DADMD), which is the maximum demand the electrical distribution network (local transformer) is capable of supplying expressed as an average per dwelling. This would provide a clear business case for property developers installing solar storage systems.

Table of Contents

List of Figures

List of Tables

Publications and Submitted Manuscripts Arising from this Project

Title	Status, Nov 2020	Journal
Wiktorowitz, J., Babaeff, T., Breadsell, J., Byrne, J., Eggleston, J., Newman, P., WGV: An Australian Urban Precinct Case Study to Demonstrate the 1.5C Agenda Including Multiple SDGs. Urban Planning, 2018, Vol 3, Open access.	Published	*Urban Planning*
Hansen, P., Liu, X., & Morrison, G. M. (2019). Agent-based modelling and socio-technical energy transitions: A systematic literature review. *Energy Research & Social Science, 49*, 41-52.	Published	Energy Research and Social Science
Understanding shared solar storage schemes as complex socio-technical systems: the WGV case study (Lead author Hansen, P.)	Presented as poster presentation	Energy and Society in Transition: 2nd International Conference on Energy Research and Social Science, held in Phoenix, Arizona, 28-31 May 2019
Hansen, P., Morrison, G. M., Zaman, A., & Liu, X. (2020). Smart technology needs smarter management: Disentangling the dynamics of digitalism in the governance of shared solar energy in Australia. *Energy Research & Social Science, 60*, 101322. doi:https://doi.org/10.1016/j.erss.2019.101322	Published	Energy Research and Social Science
Performance of a shared solar and battery storage system in an Australian apartment building (lead author Syed, M.)	*1st round revisions*	*Energy and Buildings*
Optimising community energy: An institutional approach to the study of shared energy systems (Lead author Hansen, P.)	Under Review	*Ecological Economics*
A Systematic Mapping study of current research on the use of blockchain technology-based services and platforms in electricity markets (Lead author Eggleston, J.)	Abstract accepted	*Nature Energy*

1. Introduction

1.1. Background

This research project has aimed to provide the basis for unlocking market uptake for solar photovoltaic (PV) energy solutions within strata developments in Australia, through innovative design, technology and shared governance.

By the end of 2018, over 2 million Australian households had rooftop solar PV systems (Clean Energy Regulator, 2018), but a very low percentage of PV is being installed on strata housing and apartments because a shared ownership/value model and implementation has yet to be successfully demonstrated in Australia. Nationwide, the proportion of Australia's Medium and High Density housing stock has increased from roughly 20% to 30% between the years of 2011 and 2016[2]. Apartment buildings of up to four storeys have the potential to provide a significant proportion of their electricity needs from rooftop solar PV, and meet user demand variations through battery storage. However, despite retail electricity prices in Australia rising dramatically in the past decade, only a limited number of developers are offering solar PV systems for strata developments and apartments. Other multi-unit solar developments may have shared governance but they are still rare and there is no clear Australian model.

This project develops a governance model for implementing, operating and managing solar PV, battery storage and monitoring systems in medium density strata title urban developments. A case study was undertaken at White Gum Valley (WGV), a 110 dwelling medium density, mixed use residential infill development, 4km south east of Fremantle WA.

1.2. White Gum Valley (WGV) Development

The WGV site is a Landcorp Innovation through Demonstration[3] project, situated on a 2.2ha site comprising Lot 2089 Stevens Street and Lot 2065 Hope Street in the City of Fremantle suburb of White Gum Valley. WGV was built under the framework of the One Planet Living scheme — 10 principles based on the need to live within the limits of the planet's natural resources (Wiktorowicz et al., 2018). It incorporates sustainable urban design features including a mix of building typologies, climate sensitive considerations, solar energy generation and storage, alternative water management and creative urban greening

[2] https://arena.gov.au/assets/2018/10/White-Gum-Valley-Project-Report.pdf
[3] https://developmentwa.com.au/itd

strategies. Central to the vision of the WGV development was the reduction of both carbon emission and non-renewable energy use.

Figure 1 White Gum Valley precinct (source VAM Media).

The dwelling typology at WGV consists of (Byrne et al., 2019):

- 22 detached and 1 attached (duplex) Net Zero Energy dwellings ranging in size from approximately 250-350 square metres, responding to 'beyond compliance' design controls.
- Gen Y Demonstration House (Gen Y): Three, one bedroom apartments on a 250 square metre block, with shared solar PV, battery and rainwater system. It has owner occupiers (Figure 2).
- Sustainable Housing for Artists and Creatives (SHAC): A 12 unit affordable housing project providing for professional artists working in the Fremantle area. The building also includes two shared studios, as well as shared solar PV and battery system. It has tenants, transitioning to an owner occupier model (Figure 2).
- Evermore apartments (Evermore): 24 one, two and three-bedroom apartments with shared solar PV and battery system. It has owner occupiers (Figure 2).
- Baugruppe (it is uncertain whether this will go ahead as planned): Australia's first Baugruppe project will include 17 apartments and one guest unit, and will test the German model of affordable housing and cooperative living.

- Group housing site (still in planning phase) which will include six energy efficiency survey strata detached houses.

The apartments studied in this report were Gen Y, Evermore and SHAC, all of which had a shared solar PV and battery energy storage system (BESS) (Figure 2).

Title (Developer)	Gen Y (Landcorp)	SHAC (Access Housing)	Evermore (Yolk)
Dwellings	3	12 + 2 shared studios	24
PV (kW)	9	19.6	53.6
Battery (kWh)	10	40	150

Figure 2 Summary of WGV strata residential development.

1.3. Overview of Research

This project was undertaken to test the viability of shared solar PV and BESS on strata residential developments. The following doctoral research programs were undertaken as a part of this project.

Governance of Shared Renewable Energy Systems

The purpose of this research was to advance an integrated understanding of how shared renewable energy systems operate, i.e. taking both social and technical elements into account. This led to a successful doctoral thesis by Paula Hansen entitled: Conceptual foundations for the governance of shared solar energy resources.

Microgrid Design, Installation and Monitoring for Shared PV and BESS

The purpose of this research was to analyse the performance of a shared energy microgrid in residential apartments and associated deployment effects on the network. This led to a doctoral thesis by Moiz Syed entitled: Distribution design of a shared energy microgrid for residential apartments (to be submitted in October 2020).

Analysis of Distributed Energy Resources and Network Effects

The purpose of this investigation was to clarify how we conceive of the value of distributed energy resources (DER) in practical terms. This will be reported in a doctoral thesis by James Eggleston entitled: Identifying optimal value uplift of technologies with network effects: the network effects present for shared distributed energy resources (to be submitted in late 2020).

Stakeholder Buy-in, Community Engagement and Performance

The purpose of this research was to investigate the time when people transitioned into new households as this presents a window of opportunity to study and influence household practices to gain insight. This led to a doctoral thesis by Dr Jessica Breadsell entitled: Domestic Practices and User Experiences Pre- and Post- Occupancy in a Low-Carbon Development (completed 2019). This research was funded by the CRC for Low Carbon Living.

1.4. Report Structure

Sections 2, 3, 4, 5 and 6 of this report are structured to address the four key objectives of this project as shown in Table 1. Section 7 discusses the performance and usage of the shared PV and BESS. Section 8 examines the experiences of all the stakeholders in relation to how the system has performed and section 9 presents recommendations and options for future work.

Table 1 Key objectives and sections where they are addressed.

Key objectives	Addressed
1. Identification of key factors impacting on market uptake for solar PV and storage solutions within a medium-scale urban strata development.	Section 2 Factors Impacting PV and Storage Uptake
2. A governance model and microgrid design for operating solar PV, battery storage and metering solutions for medium-density strata title urban developments.	Section 3 The Governance Model and Section 4 Microgrid Installation
3. Investigation of costs, benefits and risks of the identified governance model from the perspective of all affected stakeholders.	Section 5 Costs, Benefits and Risks of the Governance Model
4. A study of the network implications for mainstream deployment of solar with energy storage in a medium density development.	Section 6 Network Implications

2. Factors Impacting PV and Storage Uptake

Currently the lack of available frameworks and pricing incentives prevent renewable energy from being taken up in apartments and other strata developments. More specifically, there are a lack of demonstration projects, a lack of well proven governance and consumer behaviour management models, and a concern over the technical complexity of solar and storage for such applications. These are expounded on below.

2.1. Strata Titles Act

In Australia, the legal vehicle for managing ownership and accumulated benefits of a shared residential development's asset base is the Strata Titles Act, which differs from one state to another in terms of both terminology and details. The shared structures or common property (CP) is either owned collectively by owners of apartments or by the Owners Corporation (OC), also known domestically as the Body Corporate. The OC acts as trustee or agent for the owners and ultimately decide how their development is managed and what strata levy funds are used for and when. An elected Executive Committee along with a Strata Manager, is involved in making minor and major decisions for the apartment buildings. An Annual General Meeting of the OC makes decisions regarding changes to the by-laws, which rule and govern the apartment property and greater financial expenses. For these reasons, tenants have less authority regarding upkeep, day-to-day maintenance and management of the building.

The sale and settlement of electricity from the solar/storage system and mains grid is facilitated by the Strata Manager. In the case of the governance model for the solar/storage system, it is the OC who ultimately must decide how to implement it, how to operate it and will then have to appoint a Strata Manager who will agree to operate it on their behalf.

Thus there is a split incentive where development owners are less likely to invest in renewables than renters, as it is the tenants who enjoy the benefits of reduced energy costs. However, tenants are also less likely to invest in immobile technologies like solar PV, as they are unable to take this investment with them when they inevitably move on.

2.2. Financial Impediments

Sinking funds used by strata managers are a desirable option which can provide for greater cost efficiencies. However, OCs may prefer to save sinking funds or may have inadequate funds, as they only manage the CP on the owners' behalf. Approval by the OC is a necessary step for PV purchase, and with a typical payback period of 7 or 8 years, PV may be given a lower priority. Feed in Tariff (FiT) income is another serious financial consideration for the take-up of solar PV by OCs. Taxation ruling IT 2505 considers OCs as a separate business entity and therefore imposes a double taxation system.

A principal-agent problem may arise where apartment owners rent out their units instead of occupying them themselves. Without the savings from avoided electricity costs, investment in renewable energy infrastructure may not be financially viable. That is, there is no incentive for owners to invest in, e.g., a solar PV system, if they will not benefit from it directly/personally.

2.3. Electricity Regulation and Governance Model

The National Energy Market (NEM) regulatory regime does not present any barriers to the proposed governance model. In fact, changes to the laws to enable and regulate behind the meter peer-to-peer networks, and increase customer choice were implemented on 1 December 2017. The reforms have multiple benefits for consumers, but as a result they come with compliance considerations for network exemption holders in the NEM. This is discussed further under Section 2.4 Electricity Trading and Licensing.

Part of the reforms, known as "Power of Choice", include increasing access to retail competition for customers in embedded networks by creating a new accredited service provider, the Embedded Network Manager (ENM), who is responsible for market interface services for on-market embedded network customers. The need for this reform emerges from the current regime whereby only Victoria, NSW and SA allow end users within embedded networks to choose their retailer. Given these laws are in place, the Curtin University governance model is viable, subject to various compliance considerations. There are some barriers in the Wholesale Electricity Market (WEM), however, these only limit some parts of the model. Furthermore, these are expected to be reformed within the next few years.

2.4. Electricity Trading and Licensing

The NEM accommodates both types of electricity trading for the proposed governance model: trading on-site behind the meter i.e. only within the strata complex, and trading in front of the meter i.e. through the network. At present, in the WEM, residents can share on-site behind the meter, but are prohibited from sharing through the network due to two barriers: (a) Synergy's franchise: the only State-owned retailer, Synergy is permitted to sell electricity through the network to residents who consume less than 50 MWh per annum; (b) One user per National Metering Identifier (NMI): Western Power has a self-imposed restriction in its Application and Queuing Policy (AQP) that forms part of its Access Arrangement (AA). The restriction is a result of Western Power only permitting one user (i.e. the retailer) per network connection point. There is no legislation mandating that Western Power only permit one user per connection point. There have been some developments that indicate this restriction will fall away but it is still a barrier at present.

Electricity licensing (known as registration in the NEM) comes with relatively burdensome compliance requirements in all jurisdictions. In the NEM, it is administratively and legally complex to register as a Distributed Network Service Provider (DNSP) or as a Retailer, in order to convey or sell electricity. Exemptions are available upon application to the Australian Energy Regulator (AER). If a strata company is granted an exemption to allow it to own, control or operate an embedded network, it will become an Exempt Electricity Network Service Provider (EENSP). It is a condition of exemption in the NEM that network exemption holders either become an Embedded Network Manager (ENM) or appoint one when a customer within an embedded network enters into a market retail contract. This is a consideration for anyone who wishes to retail in embedded networks, and adds an additional compliance requirement which protects consumers and facilitates choice.

In the WEM, the licensing exemption regime is difficult to interpret for retailers who are part of a business model which combines on-site solar and grid electricity. This is likely to be reformed, and at present, only arises as a consideration. The result is merely that a retailer may fall under both the Electricity Industry (Solar Power Purchase Agreements) Exemption Order 2016 (Solar Exemption Order); and the Electricity Industry Exemption Order 2005 (General Exemption Order), thus having an additional administrative burden in terms of compliance with the exemption requirements.

2.5. Physical Issues

Regardless of ownership, there are a number of physical issues that may hinder the process of renewables like solar PV and BESS on apartment buildings. In high-rise apartment buildings there is less available solar PV installation area on the roof for the total amount of renewable generation required. This is a major issue. As observed from a small range of case studies, roof fixtures like air conditioning units, solar hot water systems, phone masts, aerials, safety harness fixing points, and housings for lift motors, all reduce the amount of free roof space. High apartment buildings with PV would require heavy equipment for the installation, thereby also requiring additional safety provisions, which increase capital costs.

Additionally, there is a shortage of physical facilities for installation and transmission, and along with a lack of services and equipment required for installation, this is a major physical and infrastructural issue for uptake of renewables on apartment buildings. Usually most of the required installation equipment is not locally available, and imported equipment is more expensive. Hence, the installation and transmission of renewables becomes more extravagant and sometimes unaffordable. Consequently, investors are discouraged to invest in renewables for these developments.

2.6. Potential for Uptake

This section is based on the Curtin University report to ARENA titled *Citizen Utilities*: *Unlocking Australian Strata Developments to the benefits of solar and battery storage innovations*[4].

Potential for Uptake in Australian Suburbs

Australian Bureau of Statistics (ABS) data from the 2016 census shows that 24.2% of the Australian housing stock could be classified as medium density (< four storeys). By combining data from existing solar PV uptake with medium density housing locations, this report identified the top 10 postcodes for each state and territory across Australia most likely to implement the shared solar PV and BESS governance model. These postcodes represent the middle ring of suburbs where increased density is occurring.

Potential for Uptake in Four Australian Central City Zones

Although there is no maximum height limit for the use of the governance model, physical issues begin to impact the viability of PV and BESS (as discussed in section 2.5). Beyond five storeys the ratio of floor space to roof space is reduced to the point where only a small amount of generation is produced with respect to the overall building's electricity consumption. A two-part review was undertaken to assess the 3D model of a city's central area for uptake of the solar battery storage governance model. We set out to provide a broad overview of which buildings within a central city zone could adopt solar PV and BESS. It should be noted that this review is by no means the only analysis that would be needed for each building but it was indicative of which buildings might adopt the solar battery storage governance model. This review was performed for the Australian cities for which 3D data were available and accessible (Perth, Adelaide, Melbourne, and Darwin). The results of

[4] https://arena.gov.au/assets/2018/10/White-Gum-Valley-Project-Report.pdf

identifying buildings within these zones and omitting buildings over 5 storeys in height are shown in Table 2.

Table 2 Summary of Cities Reviewed for use of the governance model

City	% of buildings suitable
Perth	31%
Adelaide	30%
Melbourne	47%
Darwin	25%

Considering the percentages of medium density housing stock in Australia in both city central areas and suburban areas, the potential for uptake of solar PV and BESS is significant.

2.7. Summary

Behind the meter trading of electricity is possible with the proposed governance model, however, trading through the network is not permitted but there have been some developments that indicate this restriction will fall away. Physical installation constraints are the main barrier for developments above four storeys. The deployment potential is an estimated 24% of the 2016 housing stock.

3. The Governance Model

The level of distributed energy is increasing in the energy market. While rooftop solar has become widely accepted by the residential housing market, few multi-unit solar-storage developments with shared governance currently exist. Until now, there has been no clear Australian model to operate them. A Strata Utility Governance framework or model, developed recently by Curtin University Sustainability Policy (CUSP) Institute was tested on medium density strata residential developments in a case study at WGV, across the three different developments (Gen Y, SHAC and Evermore).

Semi-structured interviews were conducted with a variety of project stakeholders in relation to the implementation and management of the governance model.

3.1. Description

The Strata Utility Governance Framework provides the legal, commercial and engineering information needed to implement and govern solar PV and battery storage in developments under strata and community title. It positions the strata management body as a Citizen Utility, managing electricity and financial flows, thus making the sharing of a battery storage system a viable and efficient option for owners, tenants and other stakeholders. The governance framework outlines the revenue incentive of positioning the strata management body as the utility, and a tool identifying the shared benefits, risks and costs between developers, owners, tenants, strata bodies and utilities.

Strata Utility Governance Framework Summary

- Shared battery and solar system
- The strata management body manages the system as common property
- Can be used in built strata, survey strata and community title
- Meets up to 80% of resident's electricity needs

The governance framework overcomes barriers currently precluding the uptake of solar PV panels in medium and high density residential developments. It has been designed to be adaptable and scalable to suit different development types. It has also been shown to integrate Electric Vehicle (EV) charging and electricity sharing and trading approaches.

The model benefits society by lessening the residential sector's contribution to global greenhouse gas emissions. Other benefits include the potential to

- Command higher rental returns
- Result in lower tenancy turnover and vacancy rates
- Reduce reliance on grid sourced electricity
- Enhance corporate image
- Generate revenue from on-site generation

In terms of the Sustainable Development Goals (SDGs), a shared PV and battery energy storage system (BESS) contributes to the achievement of SDG 7 (Ensure access to affordable, reliable, clean energy for all). It also contributes to SDGs 9, 13 and 17 (SDG 9: Build resilient infrastructure; promote inclusive and sustainable industrialization and foster innovation; SDG 13: Take urgent action to combat climate change and its impacts; SDG 17: Work together for sustainable development.) (Wiktorowicz et al., 2018).

3.2. Structure of the Model

3.2.1. Commercial Structure

A shared battery and solar PV array are deemed common property and managed by strata management. Each dwelling is allocated a proportion of the energy generated based on the dwelling type, a proportion is also set aside for powering the common areas. The internal price for electricity is set by the asset owners, which is lower than the mains grid price. Payment for energy is made to the strata management, which can act as an offset on the strata levy. The three developments (Gen Y, SHAC, and Evermore) were a test bed for the model. Figure 3, Figure 4, and Figure 5 outline the provision of the implemented commercial governance structures for the three sites. Figure 6 provides a flow diagram plotting out the value flows for each of the sites. An analysis of the commercial viability of the model is given in section 5.

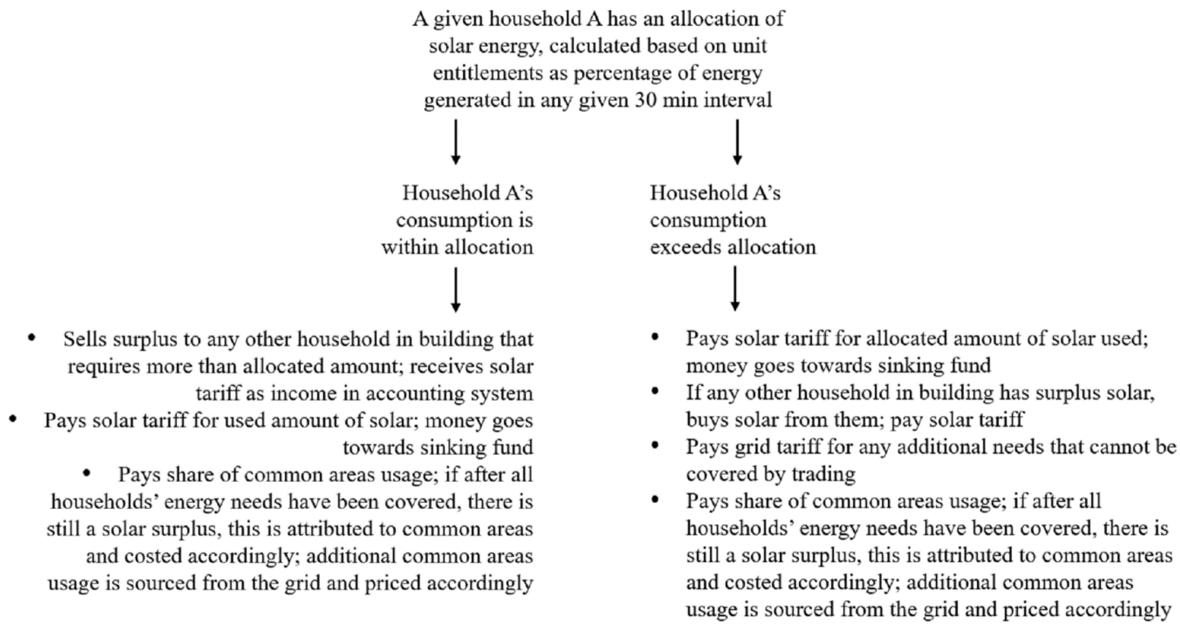

Figure 3 The implemented governance structures for Gen Y.

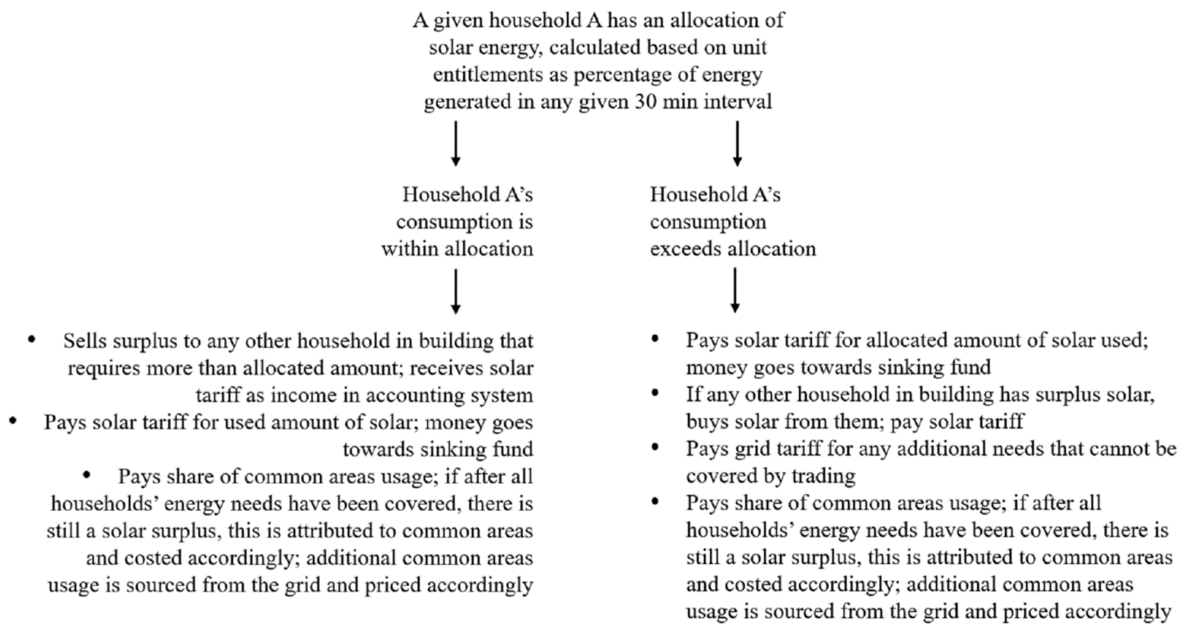

Figure 4 The implemented governance structures for Evermore.

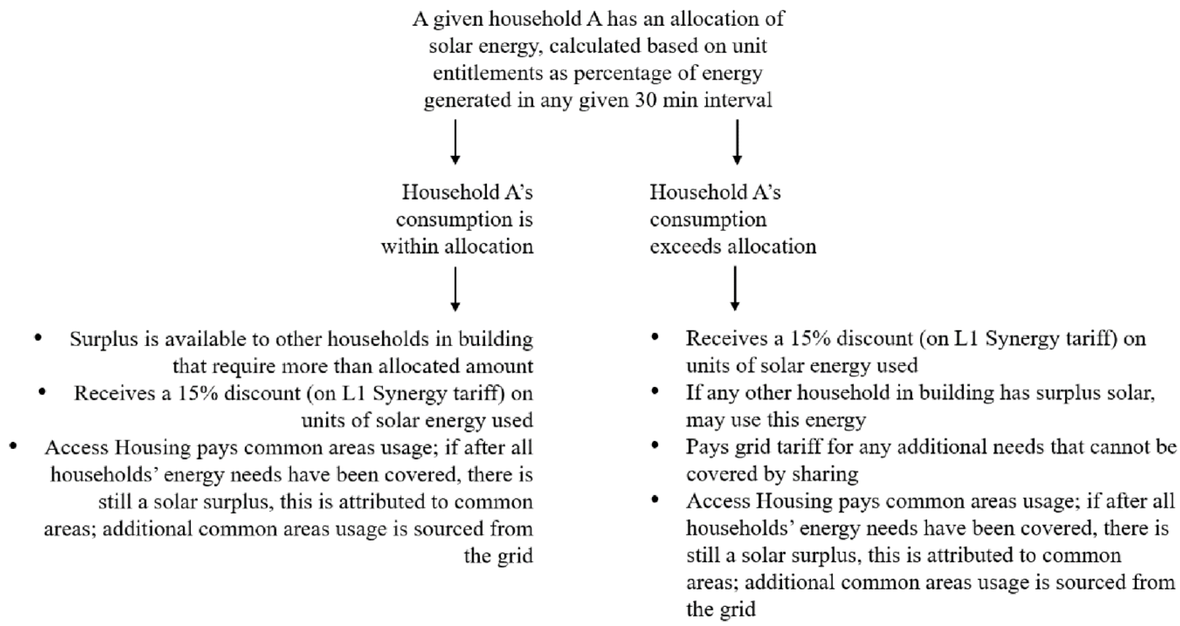

Figure 5 The implemented governance structures for SHAC.

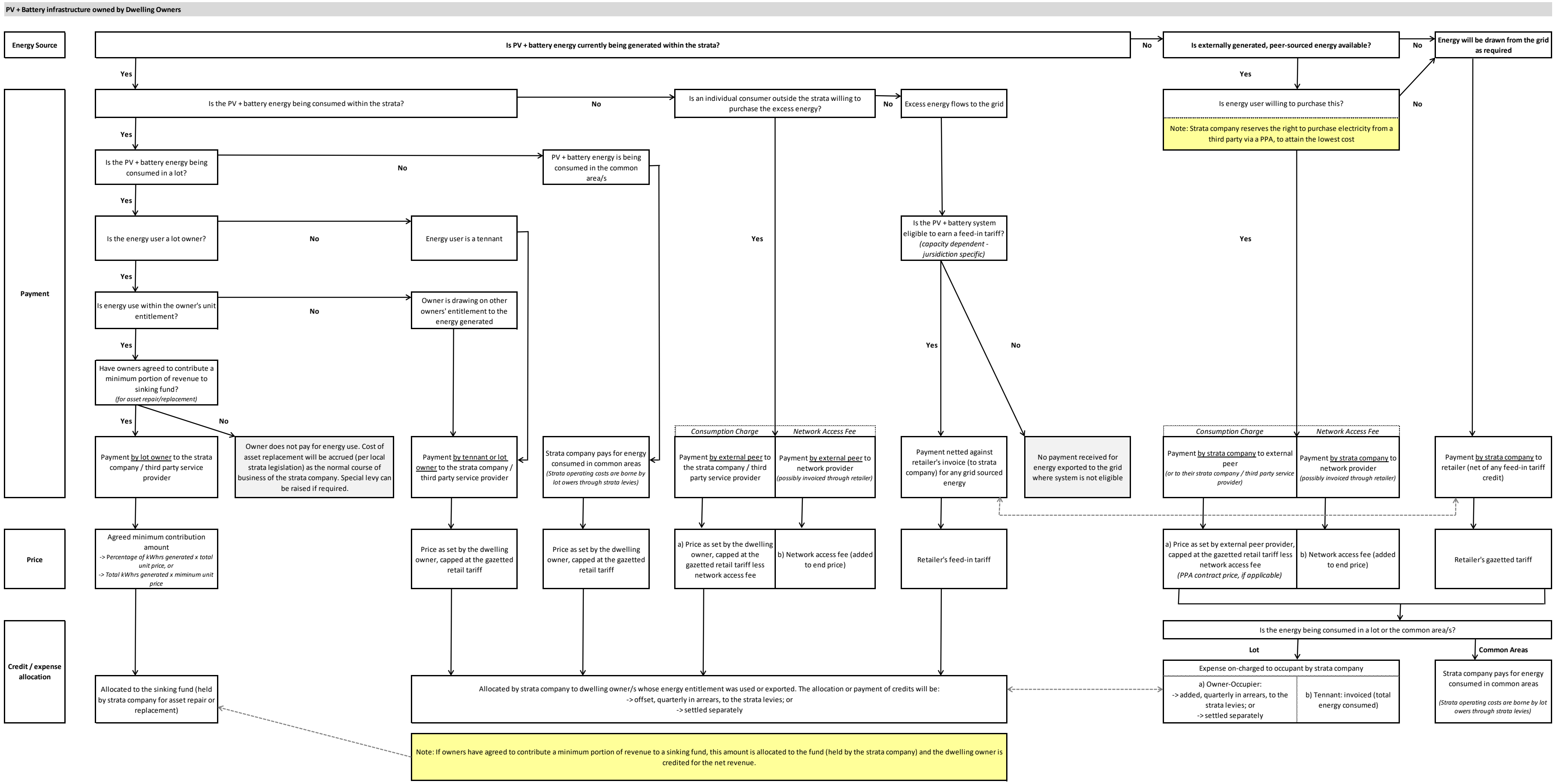

Figure 6 Value flows of the governance model.

The model structures in Figures 2 to 5 have been implemented using a peer-to-peer (P2P) trading system where prosumers (households who both produce and consume electricity) can trade self-generated electricity with consumers (Wilkinson, Hojckova, Campbell, Morrison, & Sandén, 2020). The benefit provided by this more direct trading interaction is in achieving more competitive prices than may be available through a licensed energy provider. The P2P platform used at WGV was based on blockchain technology, implemented by a third party billing company. A soon to be published review of the role of blockchain technology in the electricity market by Eggleston (2020) suggests that its use could encourage the increased size of PV and BESS for beneficially supplying electricity into the grid. It could reduce electricity system costs and be responsible for preventing widespread defection from the grid.

3.2.2. Engineering Structure

The engineering structure of the governance model involved the development and installation of a renewable energy system (shared microgrid) at each of the three strata residential developments at WGV. The microgrid comprised the following major components.

- Roof mounted solar PV panels;
- Power Core - which includes PV MPPT (Maximum Power Point Tracker) converter, inverter, and battery management system (BMS) that together constitutes a battery energy storage system (BESS);
- Metering Infrastructure: Monitoring of energy consumption through pulse meters in combination with data logger and communication devices; and
- Electrical protection equipment.

The microgrid was configured to:

1. Store solar generated energy during daylight hours in batteries.
2. Reduce the apartments electricity demand sourced from Western Power by offsetting it with solar energy during daylight hours once the batteries are charged to 100%.
3. Release the stored solar energy during the night time and when there is no PV supply available.

The control system built into the Power Core unit controls the output of the PV modules and batteries to achieve the application described above.

PV and BESS

Modelling was undertaken to size the system for each development. This involved assumptions of the electrical loads (appliances), including the water heater and cooktop, (and their time of use), as well as the meteorological data and occupancy. This data was used in a simulation to determine typical temporal consumption patterns which may occur in order to predict load profiles. An example of the daily load profile for Evermore produced by the simulation modelling is shown in Figure 7 and the monthly average electrical production is shown in Figure 8.

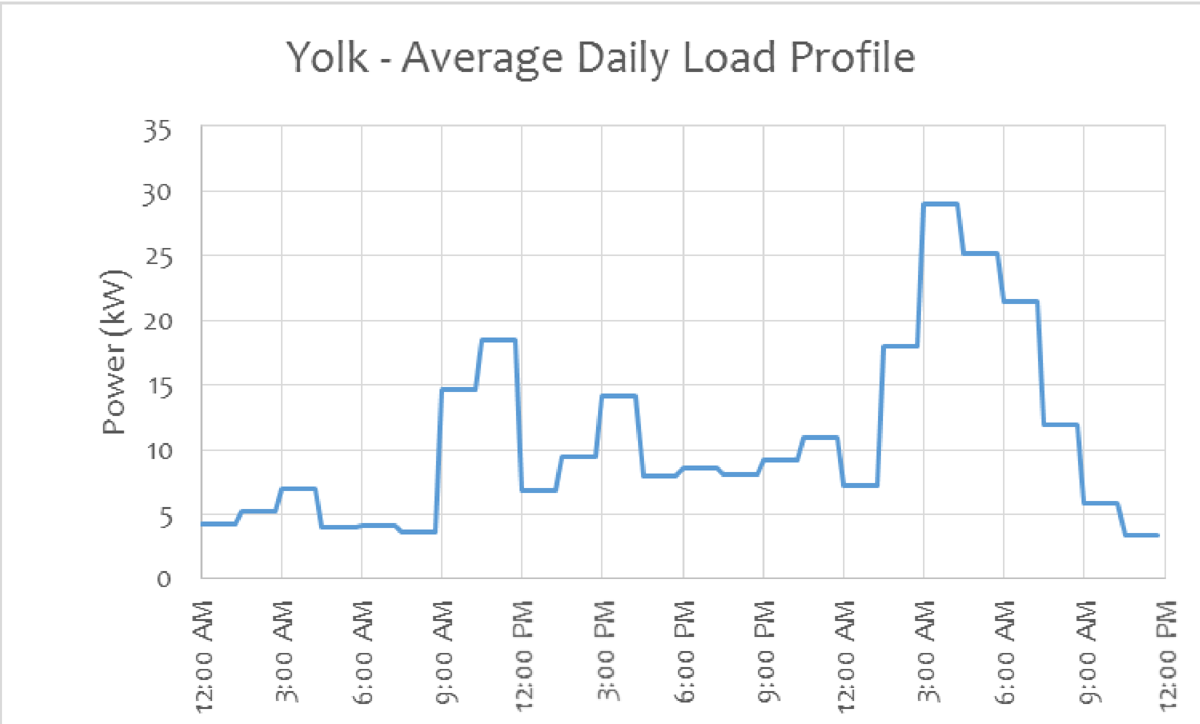

Figure 7 Yolk modelled average daily load profile.

Production	kWh/yr	%
Q.Pro 265W	104,761	82.05
Grid Purchases	22,925	17.95
Total	127,686	100.00

Consumption	kWh/yr	%
AC Primary Load	94,282	77.62
DC Primary Load	0	0.00
Grid Sales	27,191	22.38
Total	121,473	100.00

Quantity	kWh/yr	%
Excess Electricity	0.0	0.0
Unmet Electric Load	0.0	0.0
Capacity Shortage	0.0	0.0

Quantity	Value
Renewable Fraction	81.1
Max. Renew. Penetration	642.7

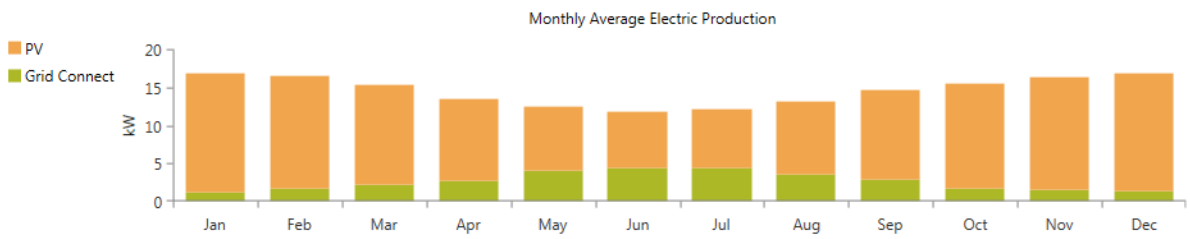

Figure 8 Evermore modelled electrical production summary.

An indicative daily performance profile for a perfectly sunny day for the Evermore PV-Battery system is shown in Figure 9. As it is clear from the plots, the PV-battery system is able to generate enough energy to cover the midday load as well as the evening peak demand. From approximately 2pm until 5pm, the system's energy generation exceeds load demand and is exported to the grid. The load is supplied from the grid between 4am until 8am, when the battery has completely discharged during the evening.

Further details of the BESS are given in section 4.

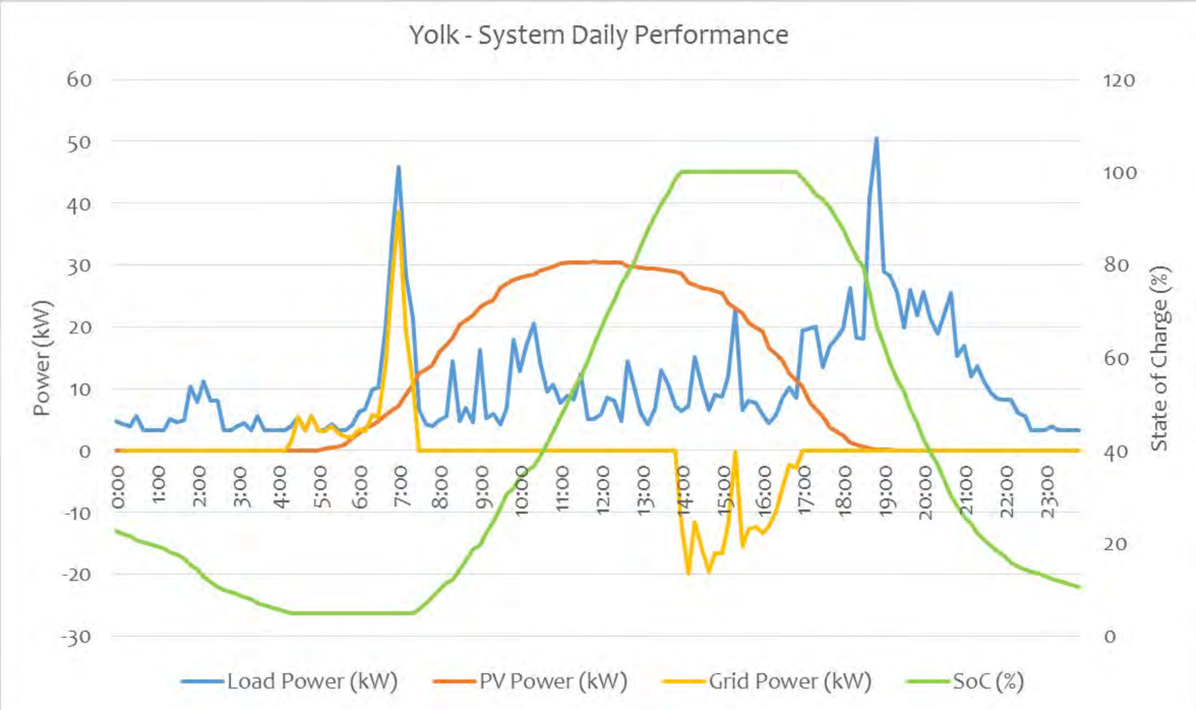

Figure 9 Evermore PV and BESS modelled daily performance.

Metering Infrastructure

Metering plays an important role in monitoring energy consumption of households as well as electricity generation from the renewables. The metering for residential units used at WGV consists of pulse meters with 1000 imp/kWh pulse weight and class B precision, whereas IEM3255 energy meters hold pulse weight of 5000 imp/kWh and class C precision. All meters are connected to a data-logger with a recording resolution of 15 minutes. The metering architecture is similar for Gen Y, SHAC and Evermore, only differentiated by the number of apartments and hence the number of Smart Interface Modules (SIMs), energy meters and water meters required.

The WGV metering architecture is described in more detail in section 4.3.

Electrical Protection

A dedicated solar switchboard was mounted adjacent to the Power Core unit in the battery room and is a central point for all AC terminations/isolation from the Site Main Switchboard. AC circuit breakers were installed to act as an isolation point from the Power Core unit and also provide over-current protection. Relays and contactors were installed to act as a remote isolation point that is triggered by a protection relay.

3.2.3. Legal Addendums

To assess the impact of Australia's legal and regulatory environment on the application of the Strata Utility Governance Model, CUSP engaged legal experts at Jackson McDonald and McCullough Robertson (details in the Legal section of Curtin University report to ARENA titled *Unlocking Australian Strata Developments to the benefits of solar and battery storage innovations*[5]). In summary, the potential of the governance model to be adapted across Australia was investigated with regards to:

- Commercial issues;
- Property laws and in particular the law governing strata developments; and
- Electricity regulation

The specific legal requirements for a project will vary across States and Territories. For electricity law and regulation, there are four different regimes, depending on the project's location:

- projects in SA, NSW, Victoria, Queensland and Tasmania fall within the National Electricity Market (NEM) in;
- projects in WA (which is not part of the NEM) are governed by separate State laws, which differ depending on whether the project is located:
    - In the south-west of WA, in which case the general State laws are supplemented by the Wholesale Electricity Market (WEM) regime which governs the South West Interconnected System (SWIS);
    - elsewhere in WA in which case WEM regime does not apply (and there may be further distinctions depending on whether the project is located within the North West Interconnected system (NWIS) or not); and
- NT, which also is not part of the NEM and has its own State laws.

[5] https://arena.gov.au/assets/2018/10/White-Gum-Valley-Project-Report.pdf

The firms' analysis of electricity regulation concentrated on the NEM and the WEM.

Tax implications of the model are summarised in section 5.2.2.

3.3. Summary

Policy and regulatory reform can make renewables adoption easier and eliminate other institutional, financial, and technological obstacles. However, further work has to be done in other states and territories particularly around community titling and rulings in relation to embedded network operators. The governance model will have to be optimised for each other state and territory, as the legal vehicle is the Strata Titles Act. This process needs all of the stakeholders in this sector, not limited to industry stakeholders, local communities, policy makers, or customers, participating in adopting a more feasible, sustainable, cost saving, and innovative energy renewables structure in the future. The engineering structure relies on good system modelling for the design, extensive installation of bi-directional meters, data logging, communications, and database management and visualisation.

4. Microgrid Installation and Operation

This section describes the installed components of the Gen Y, SHAC and Evermore PV BESS, as well as the integration of metering and monitoring, communications, a database, and a dashboard for residents and researchers.

4.1. PV system

A 9kWp PV roof mounted system was designed for GenY comprising of 36 x 250W Poly-crystalline PV modules. The PV module strings were arranged in 12 separate strings, 6 strings of 3 modules for the 1st Maximum Power Point Tracker (MPPT) and remainder 6 strings of 3 modules for the 2nd MMPT. The PV modules selected for the project were Q.PRO-G3/250 (Figure 10).

Figure 10 Gen Y solar PV mounted on the roof.

At Evermore, the PV module racking system used for the installations was a flat fixed type tin roof racking for the PV modules. Solar PV modules at Evermore are GCL-P6/72 325 sizing total capacity of 54 kWp (Figure 11). Since this is an AC coupled system, two SMA inverters of 25kW each have been connected with each array. The PV modules convert incoming solar radiation into DC electricity then through SMA to charge the batteries and also provide electricity to the loads in parallel.

Figure 11 Evermore solar PV mounted on roof.

Solar PV modules on SHAC are 75 Hanwha Q Cells which are wired into 5 strings of 15 modules (Figure 12). The total capacity of the installed PV is approximately 19.5 kWp. These PV modules convert incoming solar radiation into DC electricity which is utilised by the downstream components of the system.

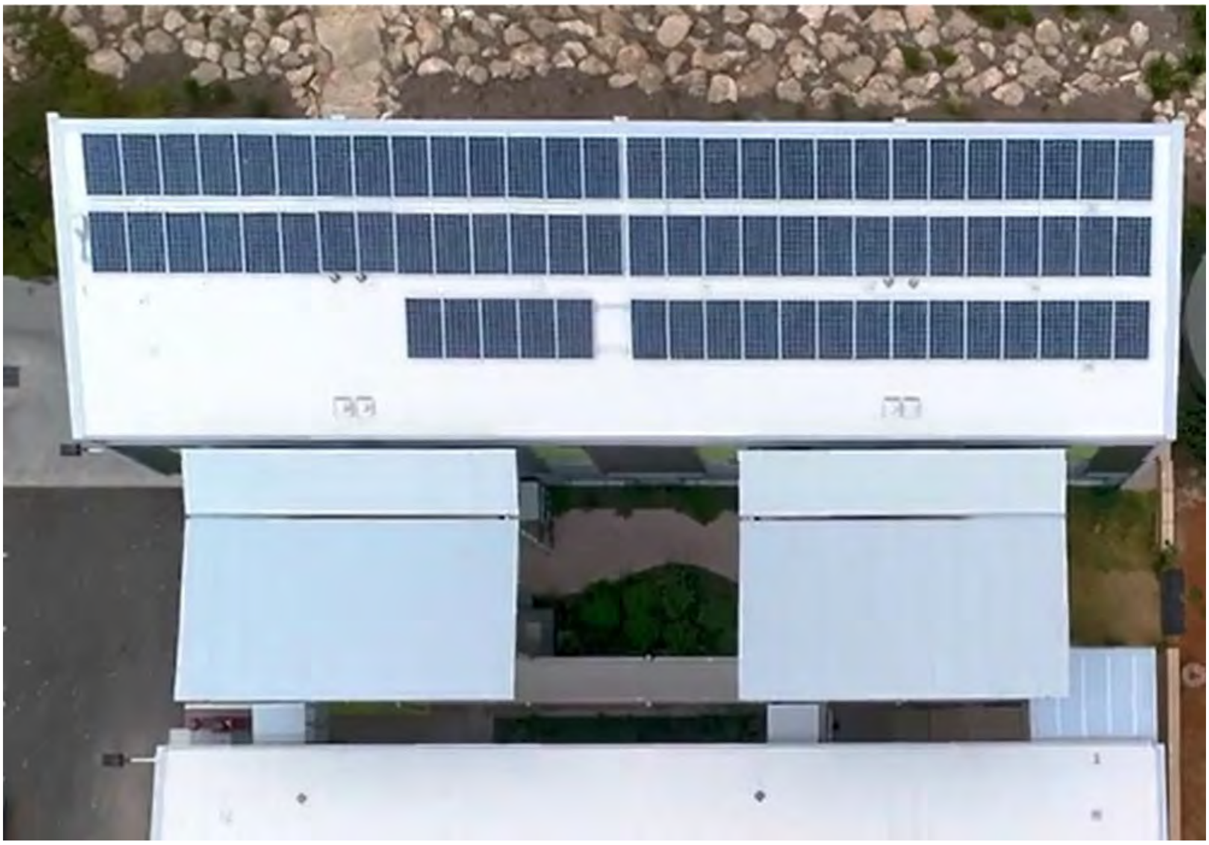

Figure 12 Installed solar PV panels at SHAC (Drone view).

4.2. Battery Energy Storage System (BESS)

The battery is manufactured using lithium iron phosphate ($LiFePO_4$) technology, which is known to be the most stable of the lithium battery technologies. The battery management system (BMS) automatically maintains the status and health of the battery system. The standard battery warranty is 5 years. The standard warranty allows the daily cycling of the battery cells to a depth of discharge (DoD) of 80% (state of charge of 20%). The proposed application of the battery system is within the operating design parameters of the system. The battery size for each development is given in Table 3.

Table 3 Battery size for each development.

Development	Battery Storage (kWh)
Evermore	150
SHAC	40
GEN Y	10

BESS or Power Core includes a DC/DC Power Converter (DCP), controls power flow between two DC sources, takes input intermittent power from solar PV and converts it into constant DC voltage. The system charges the battery using a maximum power point tracking (MPPT) feature which tracks and generates maximum DC output from solar. The BMS comprises the lithium iron phosphate (LFP) battery with management circuity to control charge/discharge and flow of energy. Through a communication bus, it transfers information about the state of charge (SOC), DoD and other necessary electrical parameters. A Siemens inverter is used to convert energy from DC into AC. A programmable logic controller (PLC) functions as a primary controller regulating DCP, BMS and inverter. The BESS enclosed in a Power Core unit is connected to a human machine interface (HMI) and has the ability to be connected to the internet and remotely monitored via a web portal. Moreover, a cloud based energy monitoring system, which takes feedback from the pulse metering and data-logger systems, has been designed to collect and measure electricity consumption by individual house units, it also displays the energy consumption graphs for individual units. Figure 13 shows a block diagram of the microgrid system at SHAC.

Compliance testing of systems (mainly Australian-Standards inverter compliance) took longer than expected (almost a one year delay) since there was no established laboratory in Australia to perform such experiments. The inverter was eventually tested in Europe, however still needed to be reviewed again by an Australian company before being certified.

The safety compliance issues from a system perspective were, firstly, earth leakage to prevent potential shock from the system, and secondly, safety of the system in terms of potential fire risk.

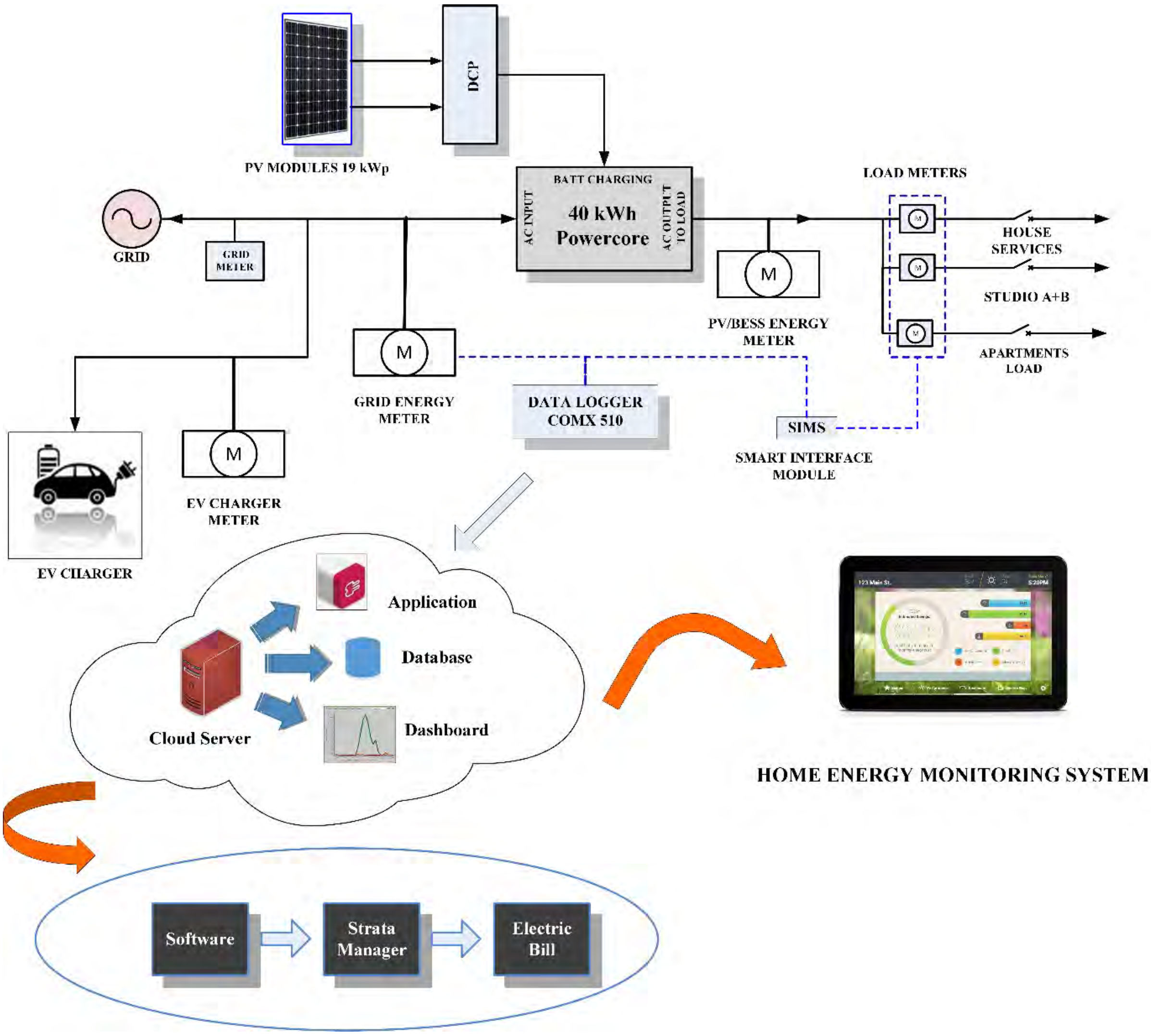

Figure 13 SHAC energy system block diagram.

4.3. Metering, Communications and Monitoring

Table 4 lists the different type of meters used for measuring energy consumption/generation. KMP1-50 and PMC-220 have been used to monitor residential electrical load consumption. The energy meters are connected to SIM10M modules via digital connections. The IEM3255 is an efficient NMI compliant energy meter which facilitates all vital measurement parameters for monitoring 3 phase electrical systems. It is bi-directional when measuring energy flow i.e. grid import and export. It is used in billing management and all types of energy measuring applications.

Table 4 Meters used for measuring energy consumption

Development	Electricity Meter
GenY	KMP1-50 (Apts), IEM3255 (Grid/Overall Load)
SHAC	KMP1-50(Apts), IEM3255 (Grid/Common area), IEM3350 (EV Charger)
Evermore	PMC-220(Apts), IEM3255 (Grid/Overall Load)

The Com'X 510 energy server is a compact data logger and is an essential part of the metering system at WGV. It collects and stores consumption of Water, Gas, Electricity and environmental parameters such as temperature, humidity etc. The Com'X 510 provides access to reports such as on-board device and circuit summary pages, as well as on-board data logging. Data can be securely accessed in real time or transmitted as a report to an internet database server. Data is ready to be processed once received by the server. The current resolution set for data obtained from Com’X 510 is 15 mins. Data can be downloaded directly or through a database server connected with Com’X 510.

The energy meter communicates with the monitoring system through Com’X 510 and Smart Interface Modules (SIM10M) on Modbus RS485 RTU protocol. As an example, the Gen Y metering architecture is shown in Figure 14.

The SQL database in the PME generates and assigns unique ID (QuantityID and SourceID) for every measuring device or meter when it gets enabled and starts measuring physical quantities. Without being enabled or with no input power, it is nearly impossible to find a device and verify the particular device or meter in the database (which already contains many sources and Quantity IDs). One proposed solution of dealing with these issues is to test the connected meter with a technique to run the electricity safely through the metering wires so it gives a feedback of the measurement to be verified manually or through a remote server connection. This technique is not an exclusive solution, however, it has the added benefit of developing Unique IDs in the database related to specific meters. This aids in building the database without waiting for the device to be switched on later.

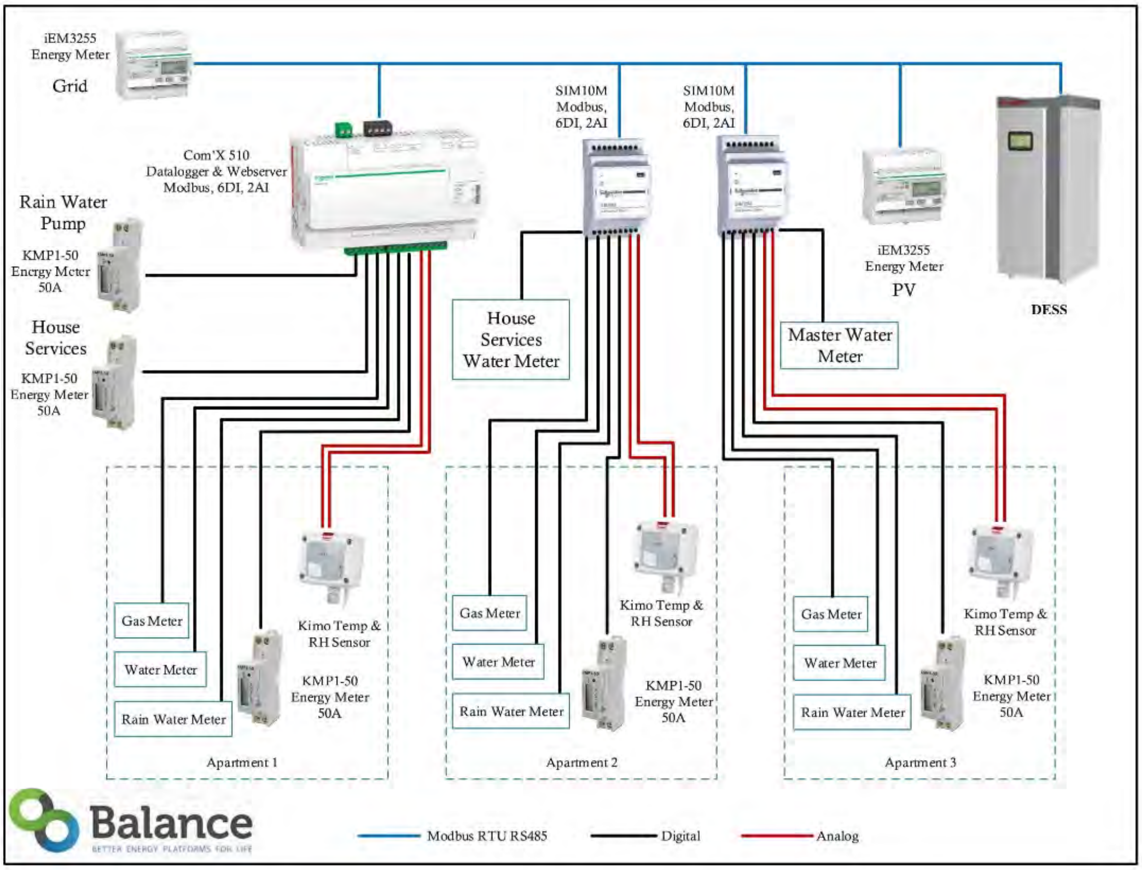

Figure 14 Gen Y metering architecture.

4.4. Electric Vehicle (EV)

An Electric Vehicle (EV) charger was included in the SHAC development. Synergy supplied a Nissan LEAF (40kWh) vehicle, and a Veefil 50kW charger (Figure 15). An EV consumption meter was installed in a small supply board beside site main switchboard (see block diagram in Figure 13). The consumption data obtained from the EV charger meter showed daily energy usage of less than 2 kWh which clearly indicates less or entirely no utilisation of EV. The daily average consumption marker (approx. 50-60 Watts) comprises of electricity power required for display and control circuitry.

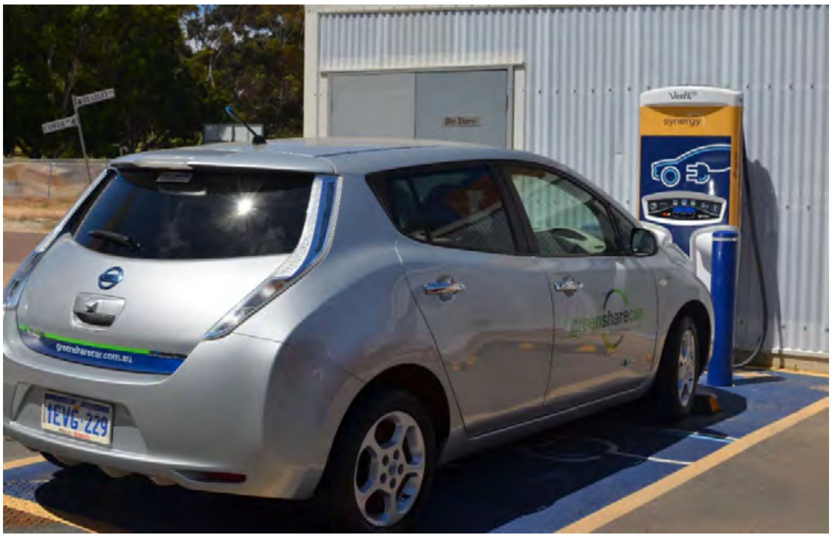

Figure 15 EV charger station and Nissan LEAF at SHAC.

4.5. Database

Data generation and sharing is indispensable to knowledge enhancement from this project. The project data consisted of two types: the quantitative metered data from the NMI compliant communication devices and Com'X 510 data logger; and the qualitative interview data. Initially, there was an absence of a central database from which contract partners and researchers could take quantitative data for research and billing purposes. The only viable solution during that interval was to transfer data manually utilising a Power Monitoring Expert (PME) application and then to send it forward in the form of comma-separated variables (CSV) files. Subsequently, the technology provider adopted the responsibility of developing and maintaining a database for the project.

There were a number of reasons why the development of a central database was delayed:

- Initially the need for a central database was not identified.
- Lack of good communication between stakeholders on forming a centralised database, and no initial decisions made on the format or timeline.
- Lack of data for a considerable period due to:
    - compliance testing of inverter systems (leading to) was delayed by almost one year (section 4.2);
    - lack of organised software structure to extract data from SQL databased used by PME; and
    - communication issues with metering architecture (this occurred mostly at SHAC from a frequently malfunctioning modem/router).

Once operational, the WGV monitoring database obtained real-time data from the energy server, pulse meters and sensors using a communication architecture (Figure 16). The real time historical data from meters and equipment on site is sent to a remote server where all data is managed.

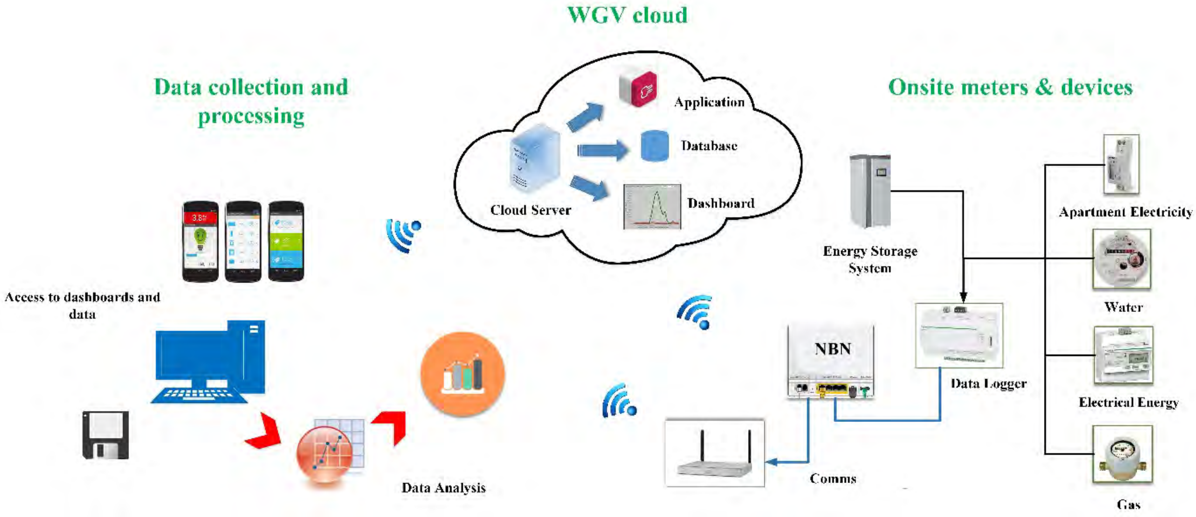

Figure 16 WGV database illustration.

4.6. Software

4.6.1. Monitoring

Dashboards deliver a pictorial illustration of real-time and historical meter data congregated at defined time intervals. This facilitates consumers to gain a quicker, more intuitive comprehension of their energy consumption and demand profiles.

The WGV monitoring dashboard demonstrates real-time data collected from the energy server, pulse meters and sensors using the communication architecture as shown in Figure 16. Com'X510 receives the real time information from meters and equipment on site and sends it to a remote server through a wireless modem with an active NBN connection. The data is then stored in a cloud server which runs Schneider Electric's Power Monitoring Expert (PME) application to further analyse, transform and organise data into visualise form to be displayed on an Eco-structure-ware web page.

WGV facilitates each tenant with an individual apartment monitoring page as well as an overview page where energy/water consumption total, energy export/import and carbon footprints info are included (Figure 17).

The dashboard provides the following benefits:

- Advanced data visualization for real-time and historical smart energy monitoring.

- Customizable end-user dashboards to analyse and share the results of energy efficiency monitoring.
- Integration with third-party data frameworks and solutions for monitoring.
- View consumption in hourly, daily, weekly, monthly or yearly increments.
- Threshold alarming and notification. Options of sending Email and SMS alerts when daily kW/kWh usage alarm set points are exceeded.
- Historical comparisons of current usage versus previous time periods under similar conditions (time, day of week, temperature).
- Data exportable to CSV format.

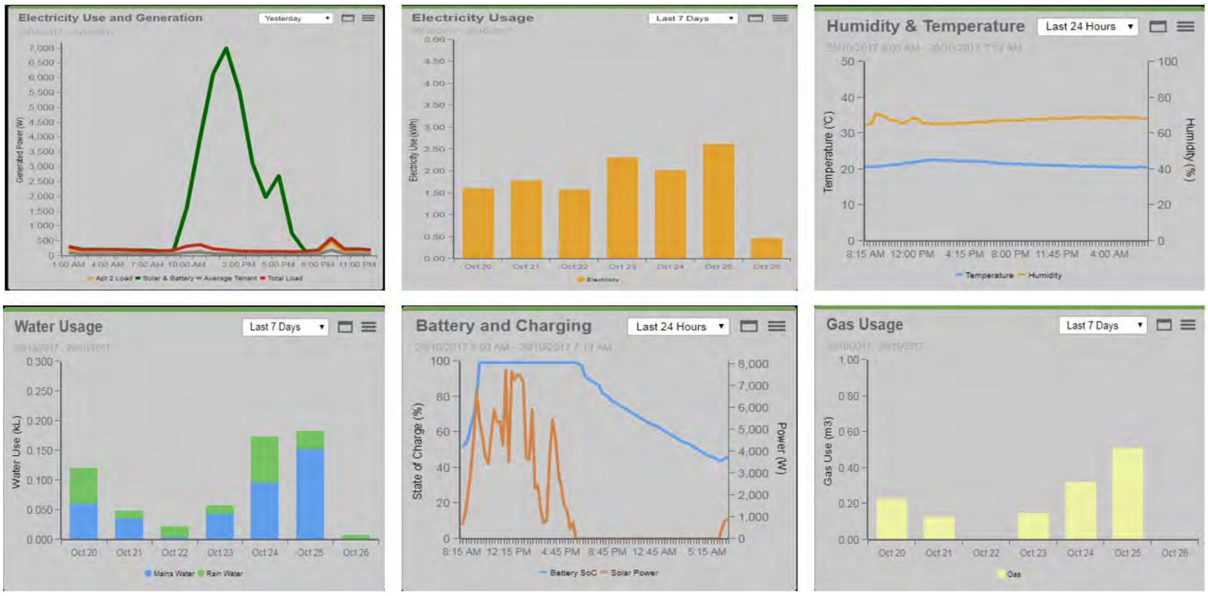

Figure 17 WGV dashboard view.

4.6.2. Trading Electricity

Renewable energy was apportioned to each unit for each 15 min metering interval. The governance model allowed for trading of renewable energy not used by one unit, to either another unit or to the common property, if these exceeded their allocated portion.

In the Gen Y development, the solar PV generated electricity is split between each unit in the apartment as well as to the CP. Residents pay their electricity bills to the strata management, with energy from the grid charged at a lower rate than charged by the state owned retailer. The P2P (peer-to-peer) platform serves as the billing system, with the renewable energy being distributed fairly, and the margin earned used to offset the levies on the strata. P2P trading has also been instigated in both SHAC and Evermore, however, the SHAC model functions slightly differently as the infrastructure is owned by Access Housing (a third party, as opposed to the owners of the units). Excess energy is shared amongst tenants on a needs basis and does not carry a separate rate.

4.7. Lessons Learned

Data Flow

Data acquisition was the most affected process in this project mainly due to its dependence on system operation and to the correct operation of the connected meters. SHAC resided on the grid for almost one year and three months without a renewable systems connection, hence, researchers and stakeholders were unable to access any data. The renewable energy system and relevant data in these ground-breaking projects hold substantial importance and should therefore be prioritised.

Engagement of Stakeholders

It is essential that the project planning phase should include all stakeholders and partner organisations.

This project is innovative in linking technology with existing rules and regulations to provide a breakthrough in the societal landscape of electricity infrastructure. However, there was a decreasing level of interest on behalf of the network operator as the project progressed. It is vital that the network operator maintains interest in the project to provide essential feedback on progress and to advance further innovation.

Compliance

Technical system compliance testing, standards verification and liaising with the network operator should be anticipated in the planning phase of the project rather than in the implementation phase. The technical requirements and Australian Standards for grid-connection of battery systems are extremely prescriptive, and the process for certifying battery systems that are not already covered by Australian Standards (*e.g.* AS4777) requires considerable time and effort.

Installation Coordination

Taking compliance issues into account, coordination played a key role in achieving the desired outcomes in the WGV project. Coordinated communication by technical experts in industry was vital in understanding both technical requirements and provision of the operational efficacy of the system. Furthermore, the WGV grid connected system design was not a system-in-a-box but an installation of separate parts, hence, it was not just a matter of compliance but also of synchronisation with the network operator. These factors are essential to consider for future installations.

Metering

To avoid delays caused by waiting for system commissioning, steps should be taken to add the metering information into the database as soon as meters start measuring the physical quantities. The advantage of this approach is twofold: Firstly, it sets up the planning and organisation required to create a database outlook beforehand; Secondly, it lays the foundation for future data from to-be-installed devices to be organised in a better way, with a minimum amount of time spent compared with organising the whole database at once.

Database

One key issue/lesson learned during project commissioning was the failed communication between stakeholders along with the lack of a proper plan to finalise data requirements related to WGV sites. Major project partners such as Solar Balance, who were responsible for organising the metering system and database, continued with maintaining the database and data logger. However, as the plan was not formed and the responsibilities were not adequately described, there was an overall confusion around who will own the data and who is responsible for database setup.

EV

End-user engagement: Access Housing have suggested that more engagement with the end-users (i.e. SHAC residents) prior to establishing the agreement with Green Share Car would have been beneficial. The applied pricing ($10/hour, plus a $500 deposit to be held for a week) represented a significant barrier for SHAC residents. The EV was not leased by any residents for the duration of the trial. A single attempt by a resident to do so led to a negative experience and may have further discouraged the community.

Technology maturity: Access Housing reported a number of difficulties with the leasing technology. Contrary to expectations, Green Share Car’s technology was not fully developed for the EV context. For example, a notification system meant to alert Access Housing of a low battery status to enable them to take action and recharge it was not working as planned.

Car sharing service operator: It was suggested that Green Share Car may not have been the most suitable partner in the trial. With operations based on the East coast, communications were slow and there was little engagement with the project.

5. Costs, Benefits and Risks of the Governance Model

In this section the costs, benefits and risks of the governance models have been studied, tested and demonstrated for the different stakeholders in three different strata lot developments. Project costs have been compared, examined and input into a financial model assessing Net Present Value (NPV), Internal Rate of Return (IRR) and savings/avoided costs. Given the timing of the project, when deducting the grant funding at the capital raising stage these projects have been mildly good investments — on a purely economic measure, however, the learnings have provided valuable insights into the widespread deployment of these systems.

5.1. Costs

5.1.1. Capital Expenditure (CAPEX)

At the completion of the project the Engineering consultant provided us a copy of the final costs for each of the solar/battery systems across each of the three sites. These types of installations were among the first in the country, as a result there were several unforeseen and unforeseeable issues at each of the sites which increased the final costs. In some instances, there were issues with inverter configuration, in other instances there were increased installation costs as a result of miscommunication between scaffolders and other contractors on site. These costs differences are given in Table 5 and the engineering details in Table 6.

Table 5 Summary of engineering costs for all sites.

CAPEX	GenY		SHAC		EVERMORE	
	Quote	Final	Quote	Final	Quote	Final
Engineering Procurement and Design						
Project Management			$13,000	$25,107	$13,000	$67,314
Engineering Design			$17,000	$19,936	$17,000	$38,885
System Procurement						
PV Systems	$8,200	$8,200	$36,000	$30,820	$107,200	$70,331
Battery/Inverter Systems			$98,215	$217,600	$ 307,083	$302,979
Monitoring System			$13,670	$4,517	$12,000	$17,530
Meters			$3,600	$9,241	$7,200	$5,785
GUI Household interface			$9,000	$27,732	$18,000	$18,000
Installation, Testing and Commissioning						
PV install						$37,428
Battery/Inverter			$24,000	$5,943	$24,000	$22,946
Monitoring System			$4,320	$5,357	$8,640	$8,640
Commissioning			$11,000	$17,832	$11,000	$7,808
Total						
Project total	**$43,655**	**$43,655**	**$229,805**	**$364,085**	**$525,123**	**$597,646**
Cost – Solar Balance in kind Contribution			$28,643		$70,417	
EPC Total			$201,162		$454,706	

Table 6 Summary of engineering details for all sites.

Site	No Dwellings	Solar PV (kW)	No of Solar Panels	Battery Storage (kWhrs)
GenY	3	9	36	8
SHAC	15	20	75	40
Evermore	24	53.6	168	150

5.1.2. Operational Expenditure (OPEX)

OPEX has been assessed as follows:

Solar PV: cleaning once per year $5.50 per panel

Battery: Curtin University estimate $300 p/a across all projects

Battery system: Engineering consultant estimate $8,000 p/a for each site

P2P platform: no charge until completion of trial.

5.1.3. Avoided costs

Savings (avoided costs) were calculated for each site assuming an A1 retail tariff. Future electricity costs (and associated costs) are incredibly difficult to predict. Unforeseeable changes to electricity policy and regulation are often implemented with little to no warning from Government. Also, changes in Government are as equally impossible to predict. All the below costs predictions have been built using cost forecast statements issued by the Australian Energy Market Operator (AEMO)[6,7]

The current pricing regime from Synergy (the sole electricity retailer in Western Australia) for October 2018 is shown in Table 7.

Table 7 Electricity costs from Synergy for October 2018.

Item	Price Inc GST
Supply charge (per meter per day)	$1.0155
Electricity charge (per kWhr)	$0.2833

Site 1/3: GenY

- Over the course of the 25 years of the integrated Solar/Battery system the savings to the residents are as follows:
    - Electricity Savings (from avoided grid electricity) of roughly $216,374
    - Avoided Fixed Daily Supply Charge (1 connection instead of 4) of $65,730
- Total savings over 25 years are estimated to be $282,105

Site 2/3: SHAC

- Over the course of the 25 years of the integrated Solar/Battery system the savings to the residents are as follows:
    - Electricity Savings (from avoided grid electricity) of roughly $522,047
    - Avoided Fixed Daily Supply Charge (1 connection instead of 15) of $262,922
- Total savings over 25 years are estimated to be $784,969

---

[6] Electricity Price Assumptions over the next 20 years here - https://www.aemc.gov.au/sites/default/files/content/7b84ddac-980a-4200-8c41-4d713dbee20a/Information-sheet-WA-final-report.PDF

[7] Planning and Forecasting - https://www.aemo.com.au/-/media/Files/Electricity/WEM/Planning_and_Forecasting/ESOO/2018/2018-WEM-ESOO-methodology-report---Peak-demand-and-energy-forecasts-for-the-SWIS.pdf

Site 3/3: Evermore

- Over the course of the 25 years of the integrated Solar/Battery system the savings to the residents are as follows:
  - Electricity Savings (from avoided grid electricity) of roughly $1,597,774
  - Avoided Fixed Daily Supply Charge (1 connection instead of 25) of $525,844
- Total savings over 25 years are estimated to be $2,123,618

5.1.4. Net Present Value (NPV)

NPV is the present value of the cash flows at the required rate of return of the project, when compared to the initial investment. In practical terms, it's a method of calculating your return on investment (ROI), for a project or expenditure. By looking at all the money expected to be made from the investment and translating those returns into today's dollars, one can decide whether the project is worthwhile.

There are two reasons for NPV:

1. NPV considers the time value of money, translating future cash flows into today's dollars.

2. It provides a concrete number that managers can use to easily compare an initial outlay of cash against the present value of the return.

Note the ARENA investment affected the NPV and is reported in Table 8 as NPV (all inclusive) and NPV (including ARENA investment).

5.1.5. Costs Summary

An adaptation of the model from Hoppmann, Volland, Schmidt, and Hoffmann (2014) was used to calculate the figures in Table 8. This table also includes the internal rate of return (IRR) or return on investment, which is the ratio between the net profit and cost of investment resulting from an investment of some resources.

Table 8 Summarised project costs.

Site	NPV (all inclusive)	NPV (inc ARENA contribution)	IRR	Est Savings on Electricity Bills	Est Savings on Fixed Daily Supply Charge
GenY	$13,965	N/A	10.04 %	$216,374	$65,730
Evermore	-$28,669	$211,330	8.25%	$1,597,774	$525,844
SHAC	-$97,796	$52,203	3.64%	$522,047	$262,922

NPV for all Three Sites

Examining an all-inclusive NPV model Gen Y would be considered a good investment positive NPV value), whereas Evermore and SHAC would be considered a bad investment (negative NPV). It is worth noting that NPV alone does not decide whether an investor would put capital into a project like this, however, is one of the components that inform that decision.

One consideration would be the timing around the quote for the engineering design. This would have been put together at the end of the year 2015, meaning we would expect the NPV to be negative as data from ARENA shows the financial viability of battery technology only came about in the year 2016[8] (refer to the ARENA modelling in Figure 18). Thus, we also modelled the NPV considering the ARENA contribution as a cash inflow in the year zero. With this approach all NPV modelling is in the positive and would be considered a good investment.

The funding of the project has occurred at the perfect time, given Government will now have an understanding how to implement this nationwide just as the technology of integrated battery/solar has become commercially viable.

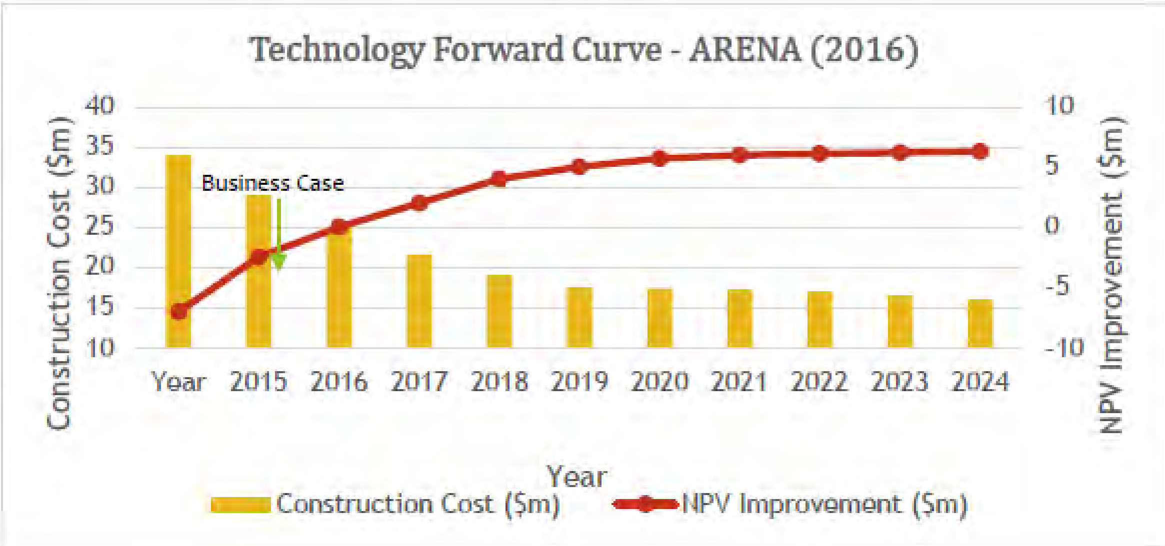

Figure 18 Technology forward curve.

[8] Technology Forward Curve - https://arena.gov.au/assets/2016/04/ESCRI-General-Project-Report-Phase-1.pdf#page=69

Savings/Avoided Costs for all Three Sites

One aspect of this project not included in NPV is the avoided electricity payments and fixed daily supply charges as a result of having an asset. An avoided cost is not considered a cash in-flow. However, there are substantial savings from purchasing grid sourced electricity with Evermore saving the most, SHAC second and Gen Y third. This is largely due to the scale of installations.

Internal Rate of Return for all Three Sites

In terms of the Internal Rate of Return (IRR) each project demonstrated a return on investment. Considering a comparison between each project, the Gen Y development promises an IRR of 10.04% (this is considered an excellent return by any measure). The Evermore site would be placed second, with an 8.25% return — still a good investment. Finally, the SHAC development would be placed last. This is by no means an indictment on SHAC, given this development is low SES housing, the system has likely been oversized. Although this means less return for the developer (for its money spent), the value to the residents or consumers would be substantial — as outlined in the avoided costs section above.

5.2. Benefits and Risks to Stakeholders

Benefits and risks to stakeholders are presented in detail in the Legal section of the Citizen's Utilities Report[9]. Some key (but not exhaustive) aspects are raised here.

5.2.1. Legal considerations

Commercial issues which a project proponent should consider include: ownership, finance, cost and consumer protection. To successfully implement this model, the ownership of infrastructure and resulting flow of funds needs to be established at the outset to ensure that financiers, insurers and electricity consumers (i.e. residents in the strata complex, and trading counterparties elsewhere) are protected and know their rights and obligations. The proponent will need to ensure that adequate agreements and other measures are in place for the model to be economically feasible and to operate as intended.

Another consideration is consumer protection, particularly in relation to the apportionment of costs. All consumers are protected under the Australian Consumer Law (ACL), which applies

[9] https://arena.gov.au/assets/2018/10/White-Gum-Valley-Project-Report.pdf

in all States and Territories. Specifically, the ACL includes a national unfair contract terms law which covers standard form consumer and small business contracts. The strata company will need to consider whether its particular implementation is caught by this legislation. If it is, it will need mechanisms that protect consumers throughout the life of the agreement to avoid having the contract deemed invalid or unenforceable.

There is a specific commercial consideration regarding the strata company's potential liability. For example, some States may impose limits on a strata company engaging in business that exposes its members to liability. For example, in some jurisdictions such as WA the members of a strata company can be jointly and severally liable[10] for the strata company's obligations and liabilities.

Strata property law also gives rise to a number of considerations, but does not present any barriers to the governance model. The most important consideration is to ensure that the strata body corporate's governing documentation give it adequate powers including acting as an electricity retailer (or contracting with a third party to outsource a retail service), acquiring, operating and maintaining infrastructure, and incurring and recovering costs.

Strata companies generally have the power to recover payment from residents. The strata company in the governance model should consider how it will prescribe the recovery of such payments. For example, will the costs be metered to each individual unit, or will the costs be metered to the whole complex? In the former case, cost recovery may simply be written into the governing documentation, or it may be the subject of a separate agreement between the strata body (or third party retailer) and the resident. In the latter case, the costs may form the administrative expenses of the strata company and the company may pass these costs through to tenants by way of strata levies with or without a precise calculation of each entitlement.

Electricity regulation is changing across Australia, in ways which will (generally) make the governance model increasingly viable, although some reforms may impose consumer protection obligations which increase the strata company's compliance burden. In most of Australia, strata bodies and residents are free to share electricity both 'behind the meter' (i.e. inside the strata development), and 'through the meter' (i.e. with people located elsewhere in the network, or with the utility itself), subject to a number of compliance considerations. In WA there are some regulatory barriers which prevent through-the-meter trading, but these are likely to be removed in the next few years. The main considerations for a proponent

---

[10] "Joint and several" liability means that each member can be held individually liable for the whole of the amount.

include ensuring that it complies with the relevant registration (licensing) and consumer protection laws, or comes within an appropriate exemption.

5.3. Summary

Quoted costs were not always the same as final costs due to the novel nature of this project.

From a purely financial aspect this project has been a good use of capital. Future financial analysis will be used to compare to this indicative financial model to verify.

The governance model was found to be viable in Australia based on Jackson McDonald's and McCullough Robertson's legal analysis of commercial, strata and electricity regulation issues.

6. Network Implications

The increasing population is leading to greater infrastructure development in urban areas. Understandably, the increase of population and groundwork expansion will lead to a greater demand for electricity consumption which will place stress on the existing grid. The integration of behind-the-meter microgrids with the centralised electricity grid must be studied before scaling up this method of energy distribution.

6.1. Distributed Energy Resources, DER[11]

Collectively, small scale renewable energy generation systems such as solar PV, battery storage, EV’s, and associated pulse metering, installed by individual consumers, have been termed Distributed Energy Resources (DER). In some cases DER called “behind-the-meter” as the energy is generated and managed on the resident’s side of the electricity meter. The DER model represents many sources of electricity distributed across the network. It is a shift away from the traditional centralised electricity generation model, where energy is transported over long distances, requiring extensive infrastructure and subsequently incurring large costs (Figure 19). DER are expected to contribute 30% - 45% of Australia’s electricity generation by 2050[12]. Already the recent increase in the uptake of DER has challenged the existing rules of the centralised system, leading to the investigation of a new model to manage DER technologies and their interactions. Prosumers will have the ability to participate in trading electricity, resulting in a more cost effective solution.

Numerous benefits become available with a DER model including:

- Low carbon generation;
- Matching demand with supply;
- Short distance distribution (lower costs); and
- Cost benefits for prosumers.

Microgrids comprising multiple DER have embraced this new model of prosumers and are at the forefront of new technologies such as digitisation, high-speed communication, cyber-physical controls and the incentivisation of DER uptake using P2P trading.

---

[11] This section has been summarised from a draft manuscript by James Eggleston entitled “A Systematic Mapping Study on blockchain in distributed electricity: towards preventing the ‘death spiral’.

[12] https://www.energynetworks.com.au/resources/reports/electricity-network-transformation-roadmap-final-report/

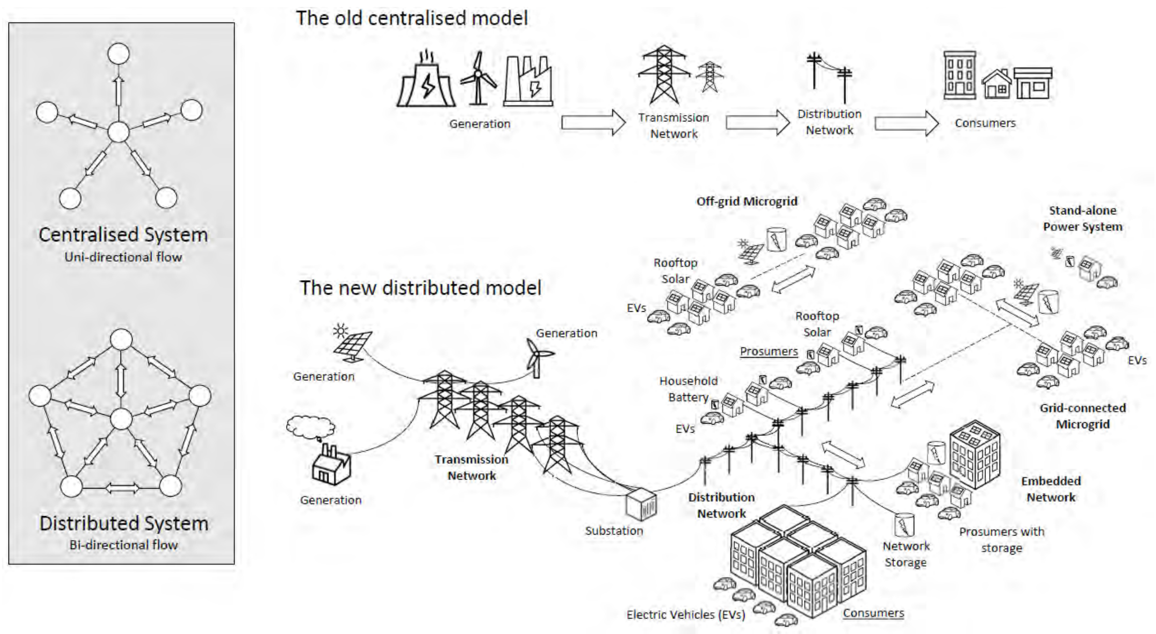

Figure 19 Comparison of the centralised electricity model and the new Distributed Energy Resources model (source: Eggleston (2020))

6.2. Network Effects[13]

Network effects can be described as the increased value to a particular network which occurs as the number of users increase. Where greater benefits can be unlocked at the same cost, simply by allowing interactions between users on a network (either physical or virtual) to take place (Figure 20).

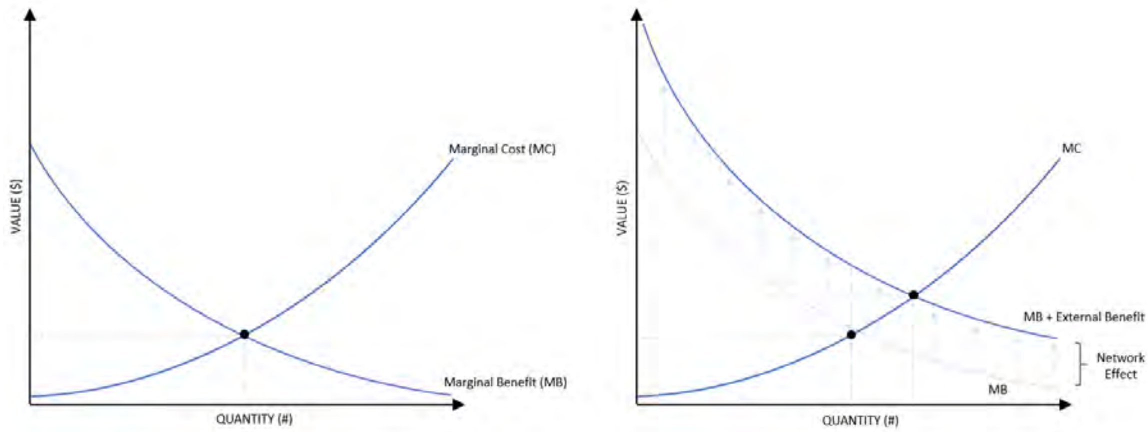

Figure 20 Graphical representation of network effects.

[13] This section is based on unpublished work done by James Eggleston "Identifying optimal value uplift of technologies with network effects: a case study of the network effects present for shared distributed energy resources".

The increasing numbers of DER will have an effect on the existing network. Network effects can be one of four types:

1) Direct — the number of connections a user can make, increases with the physical size of the network (e.g. the telephone system);
2) Indirect — the number of users increases complimentary goods associated with the network (e.g. the number of new software programs increase if there are many (and increasing) users of a particular operating system);
3) Two-sided — an increase by users in one area, increases value to users in a second area; and
4) Local — users are affected directly only by a subset of other users.

Network effects are dependent on variables such as number of users, demand, solar PV generation and battery storage capacity. The theory of network economics can be used to model this data using Beckstrom's Law, which states:

"*The value of a network equals the net value added to each user's transactions (from their standpoint) summed for all users.*"

A number of steps need to be considered to perform the modelling:

- The identification of the relevant statistical properties - such as path lengths and degree distributions, that characterise the structure and behaviour of shared DER and consumers/prosumers on networked systems (and the appropriate ways to measure these properties).
- Production of a model DER network to apply/input these properties. The model was created based on how DER networks came to be as they are and how they interact with one another.
- How to utilise the model to estimate the extent of network effects (either positive or negative) of DER on networked systems — using the aforementioned properties within set governance parameters.

Modelling has not yet been completed but leads to the conclusion that up to a point, the increased addition of DER increases value provided there is an optimal relationship between number of users, demand, solar PV generation and battery storage capacity.

Although costs to install or add additional users to shared DER increase on a linear trend, exponentially increasing benefits from local sales of excess electricity will occur from each additional user (Figure 21). This has been shown in the case study of the solar storage devices in the WGV buildings. However, there is a maximum inflexion point at which the number of DER will oversaturate the network, such that it no longer becomes viable to add further DER.

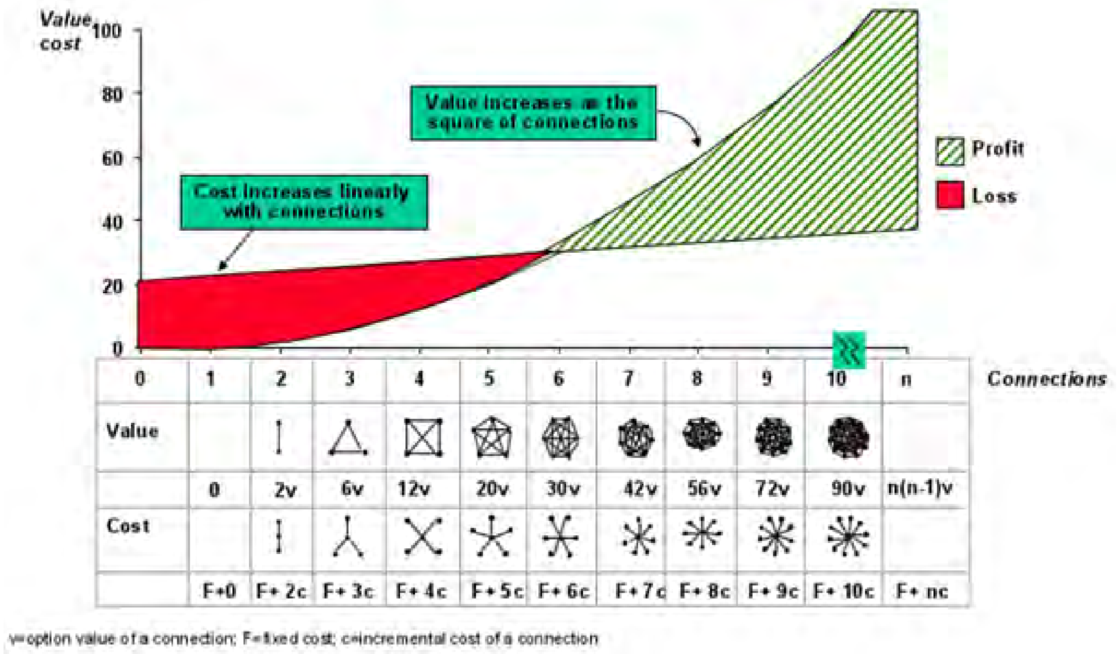

Figure 21 Relationship between connections, value and costs applicable to a DER.

The policy implications of this study demonstrate the benefits of unbundled network costs for sharing DER on a local network. In fact, in order to properly utilise the benefits of DER and to benefit from their full range of services, it is necessary to also unbundle network charges for local use.

6.3. Large Scale Deployment

This project provides a scalable and generalisable governance model for shared ownership of solar and storage in medium density developments. However, information in the following sections should be considered for the successful large scale deployment of DER based on this model.

6.3.1. Large Scale Deployment of PV Only

As the PV energy share grows, network costs will increase due to the infrastructure retrofits required to deal with bi-directional energy flow. Namely, the installation of large sized transformers with heavy wires and improved voltage regulators. Paradoxically, the effect of increased levels of PV is greater in less sunny areas. This is because PV systems are sized to meet a certain level of needs on typical days, however, on the occasional sunny days the total generation may overwhelm the network.

Intermittency in solar PV energy production due to variable insolation and weather constraints will require the operation of high-cost power generation units that counteract the variations in demand. There will be an increase in the costs, however market prices paid to PV users will decrease as more PV units connect to the grid, making further PV investments unproductive at market rates. The increase in PV generation does not necessarily cause the peak of net demand to decrease, as this mostly occurs outside the time of peak PV generation. Hence meeting the peak demand will still require the same installed non-PV generating capacity — although this may be used less with increasing solar power generation.

Advanced metering infrastructure (AMI) implementation will provide significant benefits to network businesses, permitting remote integrity testing and direct load control. However, the way bills are calculated — with a small fixed cost and a variable component — may need to change. Net metering may result in reducing the variable component, or even turning it negative. As a result, solar panel users would avoid paying most of the network's costs - although they use the network — creating an unfair structure. Metering on a large scale according to the "behind the meter" notion of the governance model would require a sophisticated network of communication and data processing equipment. However, this could be managed by use of AMI, large database servers, and careful consideration of communications and data handling.

6.3.2. Large Scale Deployment of Storage

An efficient way to reduce the negative impact of increasing PV use on distribution networks is to use technologies which store energy, such as network-wide batteries and pumped hydro-electric energy storage plants with large capacities. PV energy storage modulates energy availability by providing it during times of low insolation. Greater value can be realised by using stored energy at times of higher energy prices.

Australia's current energy storage deployment

Australia's Clean Energy Regulator (CER) has been collecting self-reported data from small generation units (SGU)[14] consisting of combined battery and solar installations in Australia[15]. This data is presented in Figure 22 and shows an exponential increase of solar PV and BESS nationally. It is important to know that these numbers are based on

[14] a solar panel system that has a capacity of no more than 100kW, and a total annual electricity output less than 250MWh

[15] http://www.cleanenergyregulator.gov.au/RET/Forms-and-resources/Postcode-data-for-small-scale-installations

information voluntarily reported to the CER and are likely to be much higher than the current 22,000 installations.

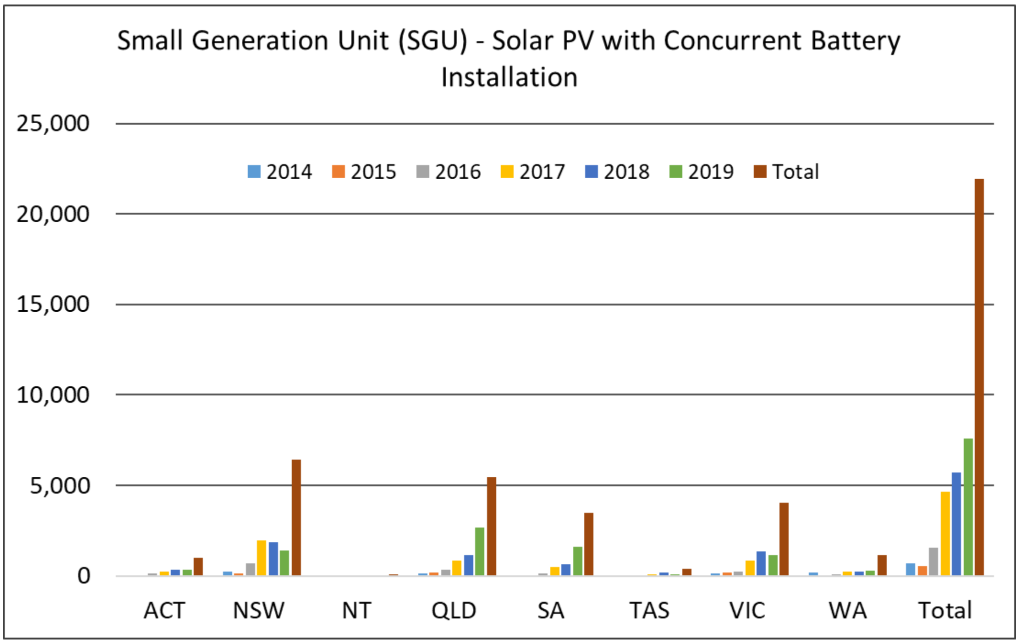

Figure 22 Household solar PV and BESS trends in Australia (Clean Energy Regulator).

As electricity prices continue to rise, energy storage provides a cheaper energy solution. In 2018, the South Australian Government announced that at least 50,000 homes would receive solar PV and BESS to build the world's largest virtual power plant (VPP)[16]. South Australia currently offer residents the opportunity to become a part of a number of different VPPs[17]. Energy storage for medium density developments may also follow suit, ensuring economic benefits for purchasers and further increasing uptake of solar PV and BESS.

An important consideration for large scale deployment of energy storage, is that it must be compliant with the installation procedures and standards set by the Clean Energy Council (CEC). Although there are existing standards for the design and installation of stationary battery systems, such standards were prepared for use with traditional lead acid and nickel cadmium batteries, and are not applicable to recent product innovations and related systems. These products include LFP batteries, and grid energy storage devices and applications. For systems similar to WGV i.e. grid connected, standards such as AS4777 must be met in regards to the electrical and general safety

---

16 https://phys.org/news/2018-02-tesla-australia-homes-power.html
17 https://homebatteryscheme.sa.gov.au/join-a-vpp

requirements for inverter energy systems connected to the battery source and grid at low voltage.

6.4. Grid Optimisation

Another important consideration when looking at the effect on the network of large scale deployment of solar PV and BESS, is grid optimisation. Grid optimisation applies to strategies performed to enhance the operational efficiency of the electrical grid. User demand varies with time and the peak power demand may be much larger than off-peak load. This creates challenges for retailers and network operators in order to supply the required demand. Grid optimisation provides stable operation, greater efficiency, longer availability and cost savings. It can also be seen as a transformation from the conventional to a smart system, and is sometimes called a smart grid.

Demand side management provides consumers with critical information on their energy usage through monitoring devices. Information could include fact sheets, dashboard visualisation and provide different pricing tariffs other than the flat rate. Grid optimisation could be achieved with the usage of distributed generation sources including solar PV, micro turbines and fuel cells *etc*., however, these are still intermittent in nature, making it difficult to manage peak demand internally. Batteries help to supply energy during peak hours and store it in off-peak periods. Some of the benefits of energy storage are:

- Shifting the load from to off peak period;
- Recuperate utilization of physical network;
- Cost benefits for end users;
- Enhance supplied and transmitted power;
- Regulation of frequency; and
- Reactive power supply and voltage stability.

Modern metering protocols such as advanced metering infrastructure (AMI) permit energy consumption data to be received and collected. Through bi-directional communication, this data can be delivered to both network providers and customers. Pulse meters can monitor grid congestion and network stability, whilst data and real-time control could be used to optimise and increase system efficiency and safe operation. Predictive analysis could be employed to forecast future functioning situations, such as rapid simulation and modelling.

Optimisation at the consumer end can be undertaken by forecasting loads, load shifting, and using balanced phases (controlling the voltage profile and feeder configuration). This facilitates consumers to reduce total energy consumption, enables network operators to balance supply and demand in a better way, and permits new actors to associate with new services.

Another method for achieving grid optimisation is through reducing reliance on grid. Grid minimisation is a procedure by which energy consumption is curtailed by effectively utilizing the renewable energy resources.

6.5. Potential Deployment

The work reported in section 2.6 determined the potential uptake of solar PV and BESS in both suburban and central city areas. In 2016 the leading state and territory for density is NSW and the ACT, delivering up to 40% density as a proportion of total housing stock. The governance model could thus likely be utilised by a sizable portion of the Australian population. This percentage is expected to rise further, as governments across the country are setting density targets to counteract the costs of urban sprawl. For example, an infill target of 47% by 2031 was set for the Perth metropolitan area in Directions 2031 (Western Australian Planning Commision, 2010). Further driven by affordability considerations, and the desire to reside near employment centres and amenities, this densification trend means that increasing numbers of Australians will be living in medium to high density developments.

The quantity of DER generation to be installed in the future could be estimated from the data in this section, however, the effects of this increased generation on the network are as yet unknown. With storage increasingly becoming the preferred option, the spill back to the grid will be minimised and therefore effects could expect to be smaller than for solar PV alone. This is an area for future research.

In metropolitan areas incentivising distributed generation and storage can rectify capacity constraints, in addition to affordably meeting network size augmentation, headworks charges, and After Density Market Design (ADMD) effects of the ambitious density targets in Australian Cities and beyond. In regional areas, encouraging communities on the edge of large-scale networks to become increasingly more reliant on locally produced generation (co-locating generation with load) can not only improve reliability, but avoid costly network upgrades to feeder lines transmitting electricity across long distances to service them.

In summary, energy storage can play a vital role in ensuring economic benefits for prospective customers of PV systems, especially in medium housing developments. The share of generation provided by PVs will thus continue to grow, without serious operational costs or economic penalties. Low-cost energy storage technology is a key enabler for the successful deployment of solar PV power at a scale needed to address sustainability issues in the future.

6.6. Lessons Learned

Interconnected local energy markets have emerged as an anticipated outcome of a large scale shift in the electricity industry away from centralised network planning.

Network effects are present in the accelerated uptake of DER and have the potential to transform legacy electricity networks into prosumer owned economic engines.

The application of Beckstrom's Law of Network Economics reveals the value of DER can increase with the number of other users sharing the resource.

Positive network effects for shared DER can occur if there is an optimal relationship between number of users, demand, generation and storage capacity. Without an optimal relationship, negative network effects can occur.

Policy implications of this study demonstrate the benefits of unbundled network costs for sharing DER on utility networks to fully conceive the true value and utility of DER in practical terms.

Further investigation needs to be done in quantifying benefits of deploying behind the meter generation and storage on the provision of network infrastructure. Specifically, its effects on 'Design After Diversity Maximum Demand' (DADMD), which is the maximum demand the electrical distribution network (local transformer) is capable of supplying expressed as an average per dwelling. This would provide a clear business case for property developers installing solar storage systems.

7. Case Study Performance

The performance of the governance model in terms of its social and market acceptance is examined in section 7.1. The practical every-day performance of solar PV and BESS and its interaction with the end-users is described in section 7.2 and 7.3. Section 7.4 discusses the performance of electricity trading behind the meter.

7.1. Social and Market Acceptance[18]

This section is based on interviews with stakeholders. Note that the lessons learned from this section are presented at the end of section 7 (section 7.5).

Key Findings Relating to Market Acceptance of the WGV Project

- The overall living experience among residents appears positive and the concept of solar-battery infrastructure is understood at a high level.
- Sustainability is important to residents and therefore the shared solar-battery system is an attractive point of difference when purchasing a property.
- The potential for reduction in electricity bills is a major incentive for residents, however, it is too early in the project for residents to ascertain the commercial advantages to them.
- There is limited understanding of how the energy system works in practice. More significantly, at this stage residents were unaware of the governance structure (the financial settlement model) and the potential for energy trading.
- While the Gen Y project was net present value (NPV) positive, the Evermore and SHAC projects returned a negative NPV and would not be commercially viable without ARENA funding at this time.
- Stakeholders generally accept that this sort of system is viable and could be scaled up, however, further information on market acceptance and a workable business model is required.
- The technical requirements and Australian Standards for grid connection of battery systems are extremely prescriptive, and the process for certifying battery systems

[18] This section provides an overview of the deliverable KS4 *"Social acceptance – Market acceptance of the benefits of the systems by dwelling buyers, occupiers and strata"*.

that are not already covered by Australian Standards requires considerable time and effort.

Key Recommendations

1. Ongoing, periodic market acceptance analysis is required to gauge the full impact of the project and levels of understanding/maturity among residents and other key stakeholders.
2. Future shared solar-battery projects be supported by a structured and comprehensive engagement and education program for strata managers, tenants and homeowners, which should include frequent touch points for the duration of the project.
3. Detailed training and ongoing supervision should be conducted during the commissioning and handover phase of the project to ensure the parties administering electricity trading/billing are comfortable with how it should work. Supervision should continue for at least one billing cycle.
4. Close engagement with apartment developers and the property sector more broadly is required to understand what their investment triggers are and how shared solar-battery systems could be an attractive and commercial proposition for them.
5. Where possible, all hardware (PV systems, inverters and batteries) should be sourced from an equipment list pre-certified by Australian Standard, the network operator, and the relevant regulatory bodies. Where non-certified hardware is required, additional time should be factored into the program to accommodate the certification process.

7.2. Energy Performance

Pulse metering enabled a study of the real-time performance of the shared energy systems across the three developments. This section briefly presents findings from this study.

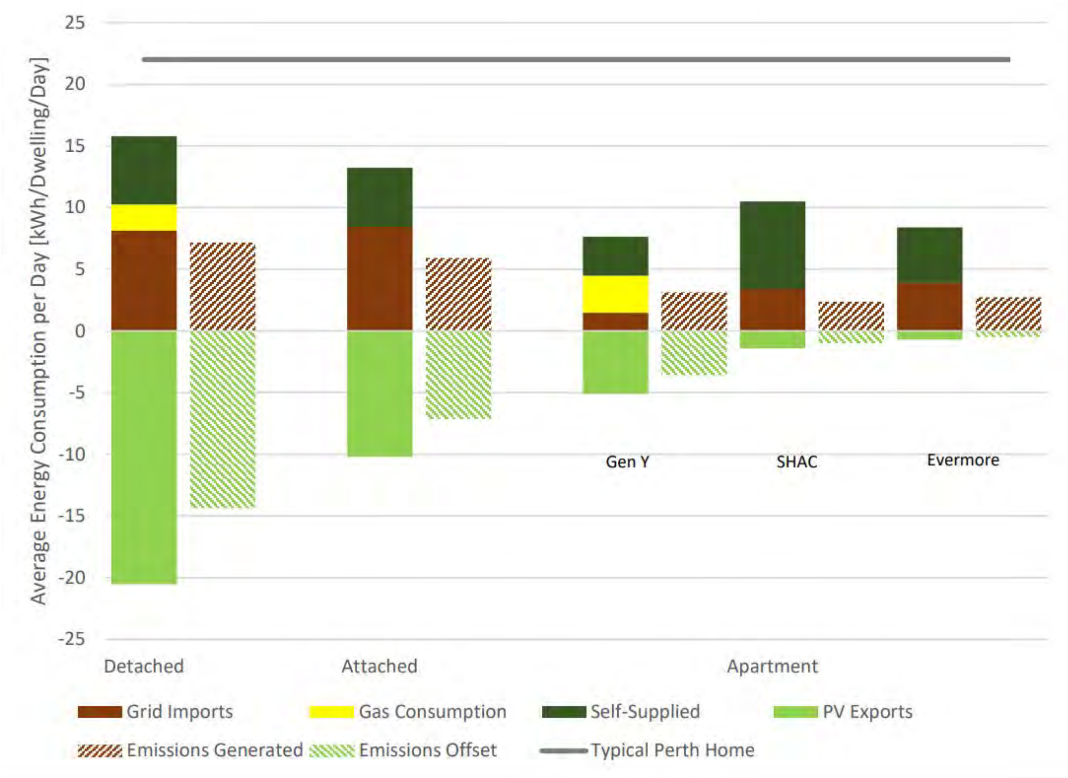

Figure 23 The average daily load profiles of the WGV apartments (Jan 2019 to Dec 2019) (source: Byrne et al. (2019)).

Figure 23 illustrates the diurnal energy profiles of each site for WGV, including grid sourced electricity, PV self-supply and export and the resultant GHG emissions and offsets.

Table 9 shows a breakdown of the energy consumption from the grid (imported) and renewables (self-supplied), as well as the energy exported, in kWh per unit per day for each of the three developments. Exports from Gen Y are significantly higher than from both SHAC and Evermore. The total consumption per unit in the larger developments is around twice that of the Gen Y units.

Table 9 Breakdown of energy consumption and exports for the WGV apartments.

Sites	Energy Imported [kWh/unit/day]	Self-Supplied [kWh/unit/day]	PV Exports [kWh/unit/day]	Total Consumption [kWh/unit/day]
Gen Y	1.5	3.2	5.1	4.7
SHAC	3.4	7.1	1.4	10.5
Evermore	3.9	4.5	0.7	8.4
Average	2.9	4.9	2.4	7.9

Figure 24 shows average monthly energy profile (kWh/day) for the three sites (grouped) to demonstrate the seasonal variation in proportion of self-supply. The daily energy demand of average apartment unit is 8.2 kWh/unit/day which is a 57% lower than benchmark of typical Perth apartment of 19.4 kWh/unit/day. On average grid imported electricity was 40% of the demand whilst renewables provided 60% of the energy demand. The average daily energy exported to the grid is 2.3 kWh/unit/day.

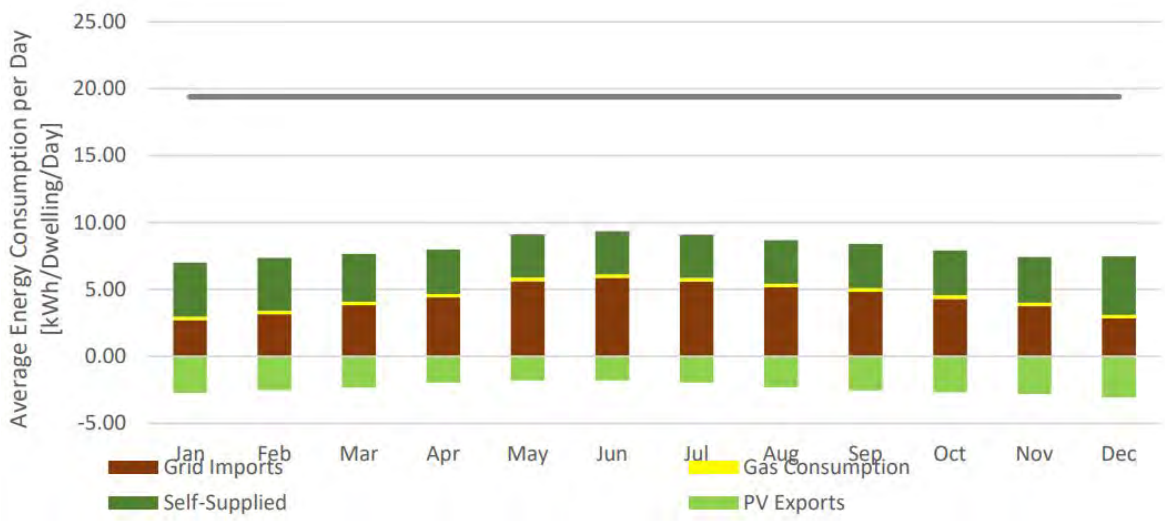

Figure 24 WGV apartments energy profile (source: Byrne et al. (2019)).

7.3. Effect of Practices

This section touches briefly on the concept of a Home System of Practices and how this has applied in the WGV case study with regards to energy use from PV and BESS.

7.3.1. Home System of Practices

A residents energy use is heavily influenced by their work and socialising routines and personal practices (Breadsell et al., 2019a). Different times of the day involve different routines within different home spaces and together these make up the home system of practices. Practices can be difficult to change if they are interlocked with other routines such as going to work, or warming the home in the morning. One resident noted:

"*It's pretty much the same. I mean, you know, if you're working, you're doing the same stuff, aren't you?*"[19]

Figure 25 shows an example of the effect of different routines on energy consumption (kWh) across one hot weekend day compared with a weekday (Figure 26) for Evermore Unit C. Spikes are indicative of particular practices such as cooking, showering or turning on the air-

[19] Doctoral thesis by Jessica Breadsell http://hdl.handle.net/20.500.11937/78566

conditioner and in this case are associated with the user being home or not. A system of practice often fixes energy use to specific points in time, making it difficult for residents to use solar at time of generation. This occurs mostly during the morning and evening peaks when people are cooking, using entertainment devices and performing household chores such as washing clothes and dishes. For households with routine practices, these occur during weekends at predictable times before and after work. On the weekend, and for those who do not work consistent hours, these are more spread out, flattening the demand for electricity. Understanding that these peaks of energy demand are deeply interlocked in daily practices and difficult to change supports the case for the addition of battery storage to decrease residents' use of grid electricity at these regular times.

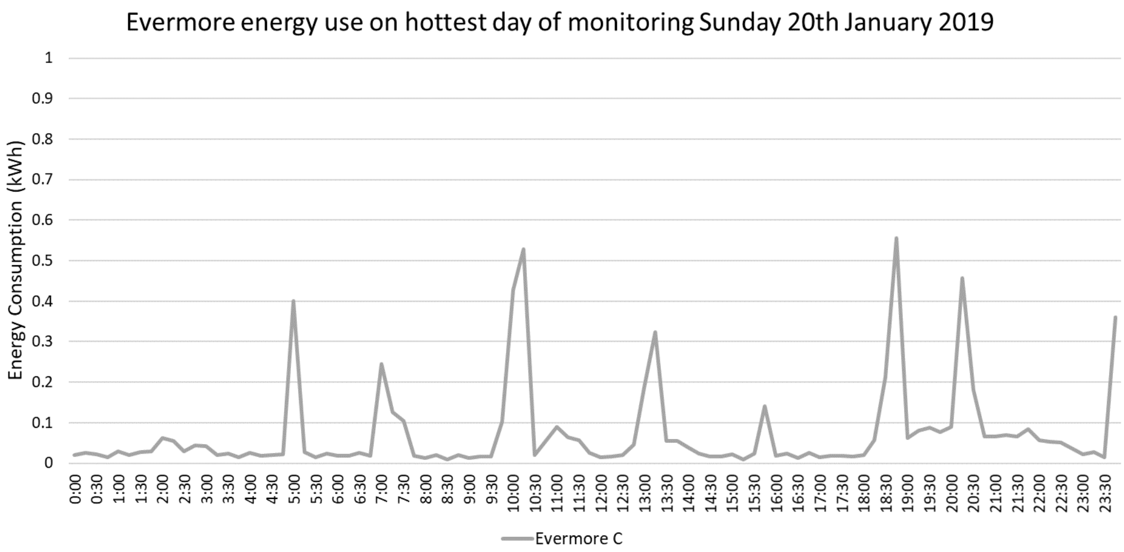

Figure 25 Evermore Unit C energy use (kWh) on Sunday 20 January 2019, the hottest weekend day during monitoring (source:Breadsell (2019)).

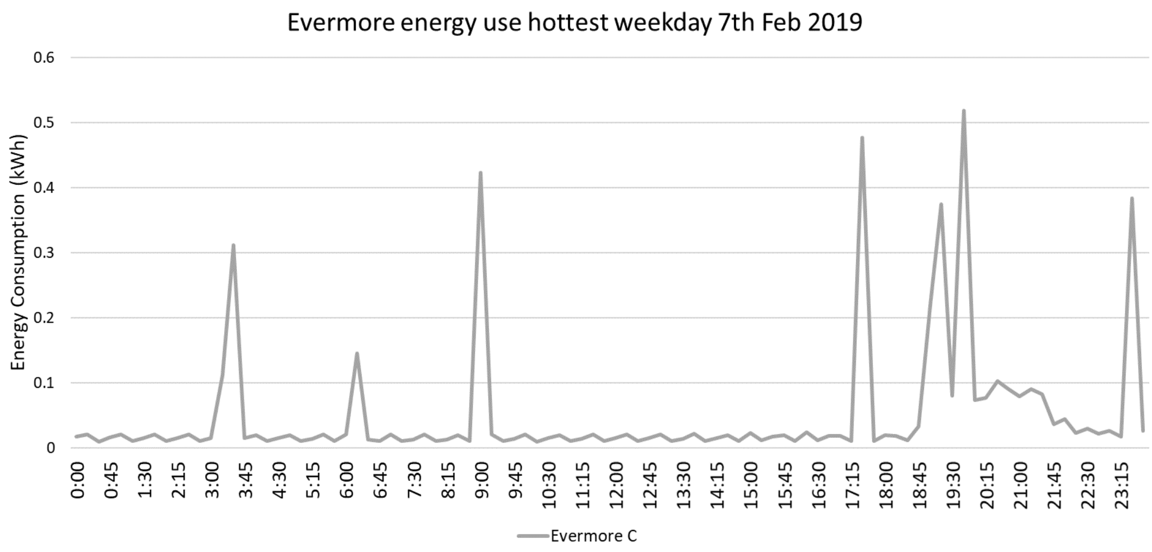

Figure 26 Evermore Unit C energy use (kWh) on weekday 7th February 2019 (source:Breadsell (2019)).

7.3.2. Heating and Cooling

Thermal comfort is related to energy consumption. Measured thermal comfort in dwellings varied (Figure 27), with most being within the acceptable range (20 to 25°C in living areas) as recommended by the Australian National Construction Code (Breadsell et al., 2019a).

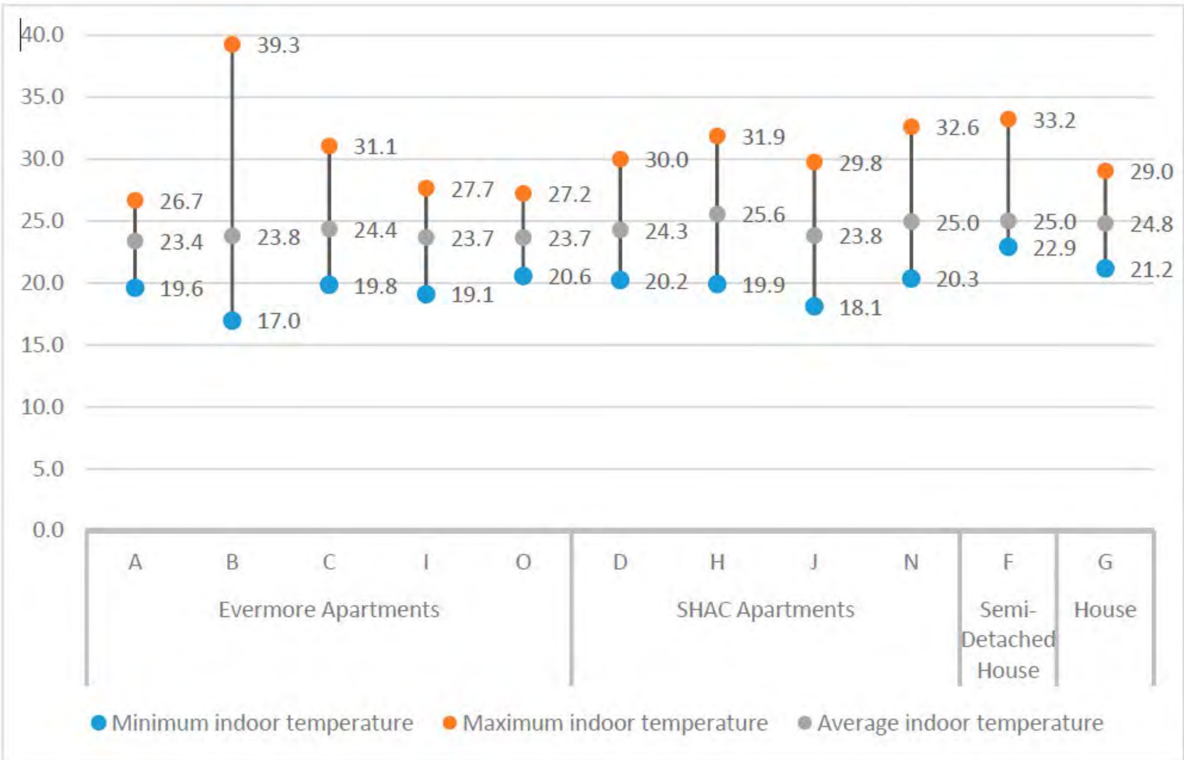

Figure 27 Minimum, maximum and average indoor temperatures in each dwelling's living area. (Source: Breadsell et al. (2019a)).

Self-reported comfort of residents also varied. The importance of solar passive design in terms of thermal comfort was highlighted by the differences in pre- and post-occupancy data. Residents who used to report putting on the air-conditioner or heater when friends or family visited their home now report that they don't need to because the thermal comfort of the dwelling is considered suitable. However, there were some residents who found their dwelling to be colder in winter. This may be due to the differences in thermal comfort between the three apartment buildings, and between the different dwelling locations within these apartments. For example, SHAC residents reported being very cold in winter, especially the south facing residents or residents whose winter sun is blocked by Evermore or by trees. Use of better quality materials and insulation in this lower cost build may have improved thermal comfort. Furthermore, the top levels of all apartments were described as being too hot and stuffy and not receiving any cross breeze. Windows on levels above the ground floor are fitted with restrictors to enable only partial window opening. Some residents have removed these restrictors to allow for a stronger breeze. Blinds and curtains had not yet been installed by some residents, however, those who have, report that thermal comfort is "*mostly okay*" but that they still use fans or AC before going to bed. The most thermally stable dwelling was located in Evermore on the ground floor between other apartments, providing it with a high thermal mass and protection from early morning and late afternoon sun, respectively.

In summary, the design of a dwelling and its surroundings has a significant impact on energy use.

7.3.3. Travel

The electric vehicle (EV) was included as part of the overall solar PV and BESS because the uptake of EV's is predicted to increase significantly in the coming years. However, the correct incentives and environment must be present for EV usage and charging to function well within the trialled energy system. Unfortunately this was not able to be tested at WGV because changes to resident's travel practices were not as significant as expected post-occupancy (Breadsell, 2019). The use of the EV was low due to the perceived prohibitive cost ($500 deposit held for one week, plus a $10 per hour fee), and residents thought they'd both walk and use their bicycles more, however, they didn't (likely due to the surrounding hills). In conjunction with the minimal public transport in the area, this meant residents were still very car reliant. But the incentives around using the EV were not great enough to encourage them to use this instead of their own vehicle.

7.3.4. Appliances and Lighting

Solar panels influenced when residents put on washer/drier/dishwasher only if they were home. The use of timers on appliances was very minimal, meaning there were missed opportunities to capitalise on direct solar energy.

Clotheslines were not provided at Evermore. Whereas the majority of resident pre-occupancy did not use a tumble drier, post-occupancy one resident commented: "*There is no clothesline here [in Evermore] which would be nice to have a clothesline, but I don't think they want the visuals of hanging clothes.*" Lack of hanging space led to increased use of tumble drying by some residents. The location of the drying lines in SHAC were too public — some items have been stolen — this also encouraged residents to use driers.

One technological innovation designed to save energy, was the installation of track lighting in many apartments. The residents reported that this system meant more lighting was being used than previously. Overall energy consumption may not have been increased however, as tracking lights were the lower energy LEDs.

The amount and brightness of external lighting around Evermore has caused problems with residents of both Evermore and SHAC, with reports of people being unable to sleep without curtains drawn, thus reducing the ability to passively cool their dwelling (Breadsell, Byrne, & Morrison, 2019b).

7.4. Energy Sharing

Energy sharing via the blockchain-enabled platform has been occurring across all three developments with varying success. Interviews undertaken by Paula Hansen and the information contained in Hansen, Morrison, Zaman, and Liu (2020) and Hansen (2020) formed the basis of this section.

The original strata manager of Gen Y did not implement the trading platform due to its perceived complexity. Residents were initially unaware that trading was not being undertaken. An alternative strata manager was eventually engaged but trading of behind the meter electricity via the software platform did not begin until around October 2019. The need for the software provider to train the new strata manager resulted in an additional time lag between contracting and the start of the sharing model in practice in October 2019.

The energy trading within Evermore has had some teething problems. The residents indicated that the strata managers did not understand how the trading system worked, and bills were not forthcoming for many months. Residents have access to the platform but it seems that few have used it. Expectations of the system have not so far lived up to the reality for most households at Evermore. Residents generally felt they did not have all the necessary information; in some cases their understanding of the sharing system was incomplete or incorrect. For example, one resident stated in their first interview that they had expected to generate significant income by selling their energy back to the grid, and even went so far as to assert they had made this part of their retirement plan. They did not re-address this in the second interview, but still had the sense they were not being given the information they needed.

Energy sharing at SHAC is slightly different to Gen Y and Evermore, as units are not privately owned by individuals but rented out. Access Housing is the owner and acts as strata manager distributing the bills to the residents. Most residents either have not been able to log in to the platform, were unaware the platform existed, or were not interested in trading. While residents liked the idea of using renewable energy and a community approach, they expressed dissatisfaction with the pricing. Because Access Housing are bound by Synergy's tariff regulations, they have been unable to deliver the significant discount on electricity costs they anticipated.

7.5. Lessons Learned

Market Acceptance of the WGV Project

While the concept of capturing and storing solar energy is well established and therefore reasonably well understood, allocating and trading electricity is a newer concept, therefore understanding of how this works and how it can be utilised is less mature.

More detailed training and education on the workings of the financial settlement system is required for the parties who will be administering the energy trading/billing systems (strata managers).

Strategic communications and a targeted education program are required to raise awareness among residents of the benefits and application of the solar-battery systems and associated trading platforms.

While sustainability is a driver, the commerciality of the systems is of greater interest to most stakeholders. More should be done to demonstrate the economics of solar-battery solutions and enable all parties to better understand how the systems can be commercially viable in the future.

Technical specifications and compliance with Australian Standards (specifically AS 4777) are significant hurdles that must be factored into future solar-battery developments.

Market acceptance is generally good, however, more detailed longer-term studies are required in order to generate more meaningful and practicable learnings for future projects.

Energy Performance

The daily energy demand of the average apartment unit is 57% lower than the benchmark for a typical Perth apartment. On average the yearly grid imported electricity from the three sites was 40% of the demand whilst renewables provided 60% of the energy demand.

The self-sufficiency rates from the three developments could be improved by optimising the systems through better control of PV exports (particularly at Gen Y and Evermore) and through use of the battery only during periods of higher consumption. On a larger scale, this could assist in smoothing the evening peak demand, thus also benefitting the utility network. Future research could examine how day ahead forecasting could be used to further optimise the systems.

The renewable system at SHAC was undersized when taking into consideration the size of households and occupancy behaviour. Most of the artists stayed at home more than those in a typical household, so daytime electricity use was higher. Hence, the SHAC microgrid was more reliant on grid imports when compared with the other two sites.

Energy Sharing

Energy trading via platforms behind the meter has the potential to create financial value for residents. However, in practice, there have been teething problems with the complexity of implementing the system and there has been insufficient data to confirm value as yet.

In general, the research found that (innovative) technology by itself does not lead to better outcomes or higher system efficiency; technology must be managed in accordance with the involved social actors (Hansen et al., 2020). Digital technology in particular may lead to unexpected complexities and consequences that reduce the effectiveness of shared energy governance systems (Hansen et al., 2020).

It was also found that if the actors designing and setting up the shared energy system are not the beneficiaries of the system (once in operation), there may be an incentive mismatch that ultimately leads to inefficient outcomes for all (Hansen, 2020). For example, residents governed by a given model/ system cannot use it effectively if they don't know its (operating) rules.

In planning and implementing shared renewable energy systems, involving the beneficiaries is crucial.

8. Stakeholder experiences

The socio-economic experiences of different stakeholders are discussed here based on work presented in Hansen et al. (2020) and Hansen (2020). These experiences include stakeholders' motivations for participation (attraction to the scheme based on its promotion), user experiences, technological experiences, as well as social and economic benefits. The expectations of participants have been compared with the realities.

The following stakeholders were interviewed regarding the effectiveness of the governance model:

- Landcorp (DevelopmentWA)
- Solar Balance (technology provider)
- Access Housing (strata manager and developer)
- Yolk
- Prestige Strata
- Gen Y (3 occupants)
- SHAC (4 occupants)
- Evermore (7 occupants)

Interviews were done in three rounds — Round 1 interviews were done from April to July 2018, Round 2 from October to December 2018, and Round 3 from November to December 2019. Round 2 interviews were conducted after it was revealed in the Round 1 interviews that project delays may have caused a lack of information reaching some participants. Round 3 interviews were performed the following year to confirm findings.

Based on an agent paradigm in which the system is viewed as consisting of interacting components (technical, financial, social), interviews focused on gaining a better understanding of these interactions and relationships. Questions aimed at uncovering agents' behaviour in relation to other system components, as well as their motivations. The interviews have therefore provided a rich set of data on the system's individual components as well as overall functioning.

8.1. Developers

The developers interviewed were Landcorp (DevelopmentWA), Access Housing, and Yolk.

8.1.1. Expectations and Benefits

One developer expected the trial of solar PV and BESS to, first and foremost, lower the cost of living for their tenants. They wished to provide access to a reduced rate of power and expected to have a positive environmental impact.

Another developer wanted to "*go down [the] sustainability path*"' and to determine if there was any demand for this type of development. The hope was that this development would be more attractive for potential residents.

One developer stated they have achieved experience and learning from the project. They believe they have reduced CO_2 emissions from energy use and provided market sector learning.

Another developer indicated they had attempted a development like this before but found it "*really hard to get a sustainable development up in a commercial kind of sense*". The project funding permitted them to test the market and see if there was demand for this in the industry.

LandCorp expressed surprise at the uptake of residence at the WGV developments, particularly given the depressed property market in the region. It is assumed that the sustainability features of the buildings made the properties particularly attractive in what is currently a slow market. LandCorp (DevelopmentWA) was also particularly accepting of the P2P trading system and is optimistic that it will be utilised more frequently as awareness increases of how trading works and how residents stand to benefit.

8.1.2. Costs and Disadvantages

The research funding made it financially viable to include battery storage as part of the Evermore development (instead of just solar PV as originally intended).

The project was very technical and it wasn't quite as easy as it first seemed, "*a lot more involved than any one quite appreciated*".

One developer was concerned about the large investment of time, with little benefit to themselves, citing the more extensive management, and understanding of technology (for billing) and tariff structure, which was required. They expressed concern that data logging had not gone smoothly and that this may have affected some data reliability. They stated that new technology "*challenges people's mindsets and how they think*".

8.1.3. Lessons Learned

One developer believes this trial has been a success and states: "*We'll try to implement exactly the same system on our larger public developments. We just see this as number one of many. We think the uptake's been enough.*" However, they do not think that residents are prepared to pay a premium for "*green*" apartments at the moment.

Another developer would not undertake a project such as this again as batteries are "*too expensive*" and they "*didn't realise challenge of actually running the system*". They are currently talking with Synergy about a simpler model with financing arrangements.

8.2. Technology Provider

The technology provider was Solar Balance, a subsidiary of Balance Utility Solutions.

8.2.1. Benefits

Solar Balance have used project to develop a range of technical solutions (e.g. microgrid platform) and successfully navigated approval processes by Western Power. They have learned about the strata environment and have obtained public relations benefits. They believed that residents benefitted overall by having green energy although they were unaware of the cost savings for residents.

8.2.2. Costs and Disadvantages

The project grant was critically important for Solar Balances' participation in the project. However, costs incurred were higher than expected. They identified the need for central project management to oversee collaboration as things became quite tense at times regarding where the money was coming from or how to perform certain tasks. More time was required to find solutions to arising issues.

8.2.3. Lessons Learned

Solar Balance believed that the project could successfully be scaled up. However, it highlighted the regulatory barriers to implementation and advised that further study on the systems is necessary to understand how and when shared solar-battery systems can be integrated into microgrids and embedded networks.

In particular, the compliance requirements of the larger battery and inverter systems for SHAC and Evermore resulted in delays of around one year. This was extremely frustrating for all stakeholders involved. However, the WGV Project compliance issues have now set some important precedents in Western Australia, and have paved the way for application of 50-100 kWh systems in other markets such as shopping centres and residential microgrids.

The technology provider was forced to assume the role of data monitoring in addition to their original stated role of commissioning the renewable systems and metering. This position became necessary as the project progressed, and the amount of data and its complexity were not fully understood or explained by the software firm. The technology provider have stated that future projects require a clear definition of all actors' roles. Whilst they are happy to continue with the data maintenance and management for WGV, they would not be keen to take on this role in any further projects of this nature.

The important lesson for future projects is to ensure the proposed systems are already Australian Standards approved, or factor in at least 6-12 months for the certification process if non-approved systems are required.

Solar Balance stated that this project "*wouldn't have been able to get done without collaboration*" however they also acknowledged that with hindsight, there may have been too much collaboration and not enough structure. The key learning was a "*really strong need for clear roles and responsibilities and commercial arrangements*".

WGV has been a *"key input into our kind of long-term strategic thinking about embedded networks and even microgrids*."

8.3. Strata management

The strata managers at WGV were Access Housing (who were also the developers of SHAC), Yolk (also developers of Evermore) and Prestige Strata (Gen Y strata managers until June 2019).

8.3.1. Benefits

Strata managers Access Housing and Yolk each expressed the view that the WGV Project was scalable and despite initial teething problems with technology and compliance issues, they believe the solar-battery systems could be mainstreamed within 5-10 years.

Both Access Housing and Yolk expressed frustration at the slow approval process for the solar PV and battery systems, as well as the need for improved communication to raise awareness of how the benefits of the systems can be maximised. Despite this, both companies are broadly supportive of the technologies and accept the trading system as a concept to be further explored in future projects.

8.3.2. Costs and Disadvantages

In the case of the Governance model for the solar/storage system, it is the Council of Owners who ultimately must decide how to implement it, how to operate it and will then have to appoint a Strata Manager who will agree to operate it on their behalf. This hierarchy has led to some interesting findings, particularly with respect to the willingness of Strata Management Companies to adopt this innovation. There was some initial pushback from the original Strata Management companies involved with this project, as the business as usual approach for managing electricity in these types of developments is traditionally either a ‘set-and-forget’ type model dividing the buildings usage by number of apartments; or an arbitrage opportunity (in favour of the strata company) where the sub-metering of each apartment is deployed and billing is offered at the residential tariff, whereas the Strata Company actually purchases bulk electricity for the building on a whole at a vastly reduced rate. This issue was resolved with residents instigating the replacement of one strata manager with another more willing to participate fully in this project.

8.3.3. Lessons Learned

There is a need for more engagement and education of strata managers. During the WGV project there have been instances where the strata manager has found the financial settlement and energy allocation process too complex, or has not fully understood the methodology that should be applied. This meant that the financial settlement system was not used to allocate energy across apartments. While this issue has not caused any significant detriment to the project, it has demonstrated the need for absolute clarity on how the allocation and trading process works.

8.4. Residents

A sample of residents from all three developments was interviewed. There was agreement across the developments that trials such as the one they are a part of, are crucial in promoting an accelerated uptake of renewable sources of energy.

8.4.1. Expectations and Benefits

Community lifestyle, housing stability and control over their own space and sustainability features were a huge drawcard for residents. Immediate decreases in household energy and water use were observed due to design factors alone. Prior to moving in to the WGV site, one resident stated: “*Moving to a low carbon precinct I believe will improve my quality of life and motivate me to make better consumer and environmental choices.*” (Resident D) (Breadsell et al., 2019b). The top three motivations for moving to a low carbon development were: sustainability features; community focus; and housing stability (Breadsell et al., 2019b).

Three kinds of benefits of having a renewable energy system emerged across developments. The first one relates to environmental sustainability and was referred to, for instance, as “*fighting climate change*”, “*cleaner energy*”, “*not burning fossil fuels*”, “*emissions need to be reduced*” or “*better for the environment*”. There appeared to be universal agreement that this was important.

The second benefit that was named by nearly all interviewees was energy cost savings. The meaning of this differed amongst people. While some seemed to expect to save money, others explicitly stated that while savings were a welcome side-effect, they were primarily interested in the environmental benefits. For example, one household at Evermore pointed out that at their previous property, having a small solar system had meant no bills had been incurred; whereas another person explicitly stated that they would be willing to pay a premium for clean energy. Some mentioned that sharing was better, both in terms of maintenance and also in terms of being about to trade electricity — with P2P providing more than a zero feed-in-tariff would.

The third benefit mentioned by interviewees may be described as a positive psychological effect related to the lower environmental impact. People stated that having solar "*made them feel good*", was a "*status symbol*" and made them feel like they were "*making a contribution*" or helping to "*establish the new paradigm*".

At Evermore particularly interviewees expressed an interest in having access to and using the online dashboard to monitor their electricity usage. They were also interested in finding out the portions of energy coming from the solar system; and in being able to manage and optimise their usage.

Relationship to Physical Systems

Based on interviews with residents within the WGV project, it seems that the overall living experience is positive. While the solar PV and battery storage systems were not necessarily the primary driver for residents taking occupancy at WGV, residents considered the sustainability feature to be a plus and that the solar-battery system was a factor in their decision to purchase. Several interviewees stated that sustainability was important to them and that if they hadn't moved into the WGV developments they would have looked into getting similar sustainable features installed at their previous home.

One interviewee from the Gen Y developments stated that they were: *"Attracted to the holistically sustainable and well thought through design of the building."*

The concept of solar PV generation and battery storage was well perceived by residents. Most were able to describe at a high level how the system worked and understood the concept that the battery storage system works in tandem with the PV system to supply electricity outside of daylight hours. It was generally accepted that the application of the solar-battery system "*seemed like a sensible idea*".

Relationship to Governance Systems

The communal ownership of the systems, the governance model and the financial settlement systems in place in the WGV Project developments were less well understood. For many residents the interview with the CUSP researcher was the first time they became aware of the governance model and that electricity is allocated to each apartment. There was no awareness of the ability to P2P trade and limited understanding on how the P2P trading system works.

This asymmetric knowledge amongst stakeholders may partly be linked to the technical aspects of the project *i.e*. some stakeholders had more knowledge about the systems and processes than others. The poor sharing of this knowledge led to residents feeling unable to assess their own energy performance. The responsibility of providing knowledge of how the systems and process worked was not clearly allocated to a single stakeholder.

One example of this, is that the complexity of the energy sharing process meant that although the residents had permission to alter the sharing agreements, their lack of knowledge about doing this, prevented them from attempting this. The case of Gen Y demonstrates that owner-occupiers can and do take action when empowered to do so. The original strata manager of the three apartments at Gen Y simply distributed the energy three equal ways. When one, more energy conservative, owner/occupier became aware of this, they were motivated to request a change of manager such that energy distribution would be distributed based on consumption. They were annoyed that they were paying for "*other people's air con*".

Some residents felt dissatisfied with the performance of the governance system. They stated that although the third party billing company and Evermore developers continued to publicise the development as being successful, they were not addressing the issues which affected the residents. They reported that none of the participating organisations had sought their feedback and they felt that there was no accountability.

8.4.2. Costs and Disadvantages

With regard to the potential for lower electricity bills, residents all considered that this was desirable and likely to be the most attractive aspect of the system. However, few residents were actually aware of any savings due to either not receiving any/many bills or not understanding or being able to disaggregate the information provided on the bill.

In general, there appears to have been little reported use of the billing platform by SHAC residents. According to one resident "*most people don't check the platform*" as far as he knows. Another resident stated they have login details but cannot log in. And another, that when checking online, "*it is difficult to understand what you are looking at*", and the bills sent to residents by Access Housing don't include amounts of electricity.

8.4.3. Communication and Education

SHAC interviewees (who were interviewed as a group) remarked that "*there needs to be more explanation*". While on one hand they felt that as SHAC residents they had not yet received sufficient information regarding the SHAC energy set-up; on the other they pointed out that a lack of education (of SHAC residents) is a missed opportunity in educating others and therefore promote the uptake of renewable energies. Since "*we are the people who will tell others about it*", they felt that an adequate level of understanding was paramount. SHAC residents further expressed an interest in better understanding of the pay-back period of the system and whether the cooperative could buy the infrastructure off Access Housing in the future. Along similar lines of thoughts one SHAC resident stated that the SHAC cooperative had been interest in buying and implementing a solar system at the site even before the project started and were subsequently disappointed at the loss of control associated with Access Housing having ownership of the system. The SHAC cooperative is looking to replicate their model in the future and share lessons learnt with other communities (this includes but is not limited to the renewable energy system).

One Evermore resident stated that ongoing education was missing. Once the technical systems were put in place there has been a lack of information about using the system: "*it's like everyone sort of did the project, not everyone, but the majority of people who were involved in the project, did it and then sort of went, okay, done*." There were difficulties in obtaining further information: "*trying to get a bit of information on … tracing things… is a little bit difficult. I guess that's to be expected when something is new*." One Evermore resident would like updates, email communication or just a more user-friendly site (billing platform website). Another said that information about the best (most energy efficient) time to use appliances was not given *i.e.*, being informed "*whether it's better to have your showers in the evening or in the morning*". "*If they said, the sun is shining, the best time to put a load of washing on is in the afternoon, then I would definitely do that. But yeah, that's actually a really important point because that wasn't explained to us*".

Another resident believed more upfront information should have been provided and stated: "*I think it's a fantastic idea. I really do think it's a fantastic idea but I think that the people who'll be moving in need to know what is required of them before they even contemplate moving in.*"

8.4.4. Lessons Learned

Lacking clarity regarding their roles and responsibilities in the project, and a shared vision, none of the stakeholder involved in the design and implementation process felt responsible for informing and educating the residents. The responsibility of providing knowledge to the residents of how the systems and process worked, needs to be clearly allocated to a single stakeholder. This is further discussed in Hansen (2020).

Information about the sustainability features and the energy systems was made available to residents via the internet and printed literature, however, an important lesson is that residents will not necessarily seek out this information for themselves. It is therefore important for similar future projects that a detailed program of engagement and education be provided for residents. This could take the form of written information, workshops, regular communications from the strata company, and periodic information sessions that provide hands-on guides to how the financial settlement and trading systems work. Most importantly, this information should be disseminated in such a manner that real-life benefits — in quantitative and qualitative terms — be shown to residents as an example of what they can achieve. Potentially the most powerful messaging could involve demonstrating what cost savings have been made and foregone by residents in their apartment building during a billing period, along with practical advice on simple behavioural changes that will help residents save money. Communication with residents should be extended for a longer period of time to ensure access and comprehension of data are satisfactory. This is especially critical considering the innovative nature of this development.

The communication of a shared vision for the project across all stakeholders is essential. This may prevent some of the (minor) misunderstandings, lack of trust and operational inefficiencies which were a result of a lack of resident engagement.

Residents need to be provided with easy and understandable access to their real-time energy performance data in a timely manner.

To ensure immediate change in a system, replacing the technology used with something more efficient results in an immediate effect if used correctly. This is evident by replacing the electricity source to solar PV, without residents having to change their daily practices. Another option to encourage resident changes in the system is to target to “why” element, or the meaning as to why the practice is being performed. This focuses on the social norms and values driving a practice and can be targeted especially well through recommendations in social networks.

Social networks of friends and workmates were the predominant way in which residents heard about the WGV project. These networks might be used by real-estate agents to increase awareness of, and interest in, future low carbon developments (Breadsell et al., 2019b).

There was an overall feeling that projects like this are important — "*this research is going to enable more companies to be educated, to take this on and more medium density housing or apartments to be built with renewable energy which is the way of the future so I think it is really important*".

8.5. Summary of Lessons Learned

The main challenge associated with the interview data collection process is linked to the timing of building construction and technical system delivery. Occupants of the SHAC and Evermore developments were interviewed between November and December 2018, shortly after the solar storage systems went online. Occupants were therefore unable to comment in detail on their experiences with the technical system or the billing. Occupants at Evermore only moved in the second half of 2018 and therefore additionally had limited abilities to comment on their overall experiences of living at WGV.

The interviews revealed a considerable degree of divergence between stakeholders' levels of understanding and knowledge of the system design, roles, and project progress. Beliefs and opinions regarding system functioning also varied greatly. Participating organisations were — unsurprisingly — knowledgeable with regards to their own specific role but generally had little information regarding the particularities of other stakeholders' activities. While this is to be expected and may in part be attributed to the difficulty of adequately framing questions,[20] this apparent lack of communications led to misunderstandings. Hence communication is key — between partner organisations, and partners and residents. For example, residents governed by a given model/system cannot use it effectively if they don't know its (operating) rules; in particular, the sharing of electricity within Gen Y did not function as intended initially (through trading), as the lack of knowledge of the residents meant they were unaware they had the ability change the electricity sharing rules rather than accepting the equal three-way split instigated by the strata management company. Residents generally

[20] Given the different backgrounds and roles of project participants defining system boundaries was a challenge in guiding the interview. Initial questions therefore generally referred to "the shared solar storage" rather than "the governance model" to allow interviewees to speak to their own interpretation.

had a poor understanding of how their solar and battery storage systems worked, which was linked to a lack of information being available to them.

Prominent motivations for residents to move to WGV were a general interest in sustainable living/reducing their carbon footprint, and a sense of community living. In the view of residents, trials such as this are crucial in promoting an accelerated uptake of renewable sources of energy.

The trialled set-up for energy sharing led to the need for an additional role, namely that of data monitor; given the novelty of the trial, stakeholders were initially unaware of the need for such a role; it needs to be explicitly accounted for in future projects

9. Recommendations and Future Work

9.1. Recommendations

It is recommended that the commissioning phase of any future projects involves hands-on training with strata managers (or whichever party will be administering electricity billing/trading) for at least one complete billing cycle. There is also a requirement for prescriptive and easy-to-follow instructions on how to administer the systems over the longer term.

It is recommended a detailed timeline of education and engagement activities, with key milestones, be developed for residents, strata managers and any other interested parties involved in similar shared solar-battery projects. This should be and executed in parallel with the project commissioning, handover and the first 12 months of operations. It would also be beneficial to include a two-way feedback loop to enable residents and administrators to share learnings and take greater ownership of the financial settlement models and trading systems.

Future shared solar-battery projects should be supported by a structured and comprehensive engagement and education program for strata managers, tenants and homeowners, which should include frequent touch points for the duration of the project.

Where possible, all hardware (PV systems, inverters and batteries) should be sourced from an equipment list pre-certified by Australian Standards, the network operator, and the relevant regulatory bodies. Where non-certified hardware is required, additional time should be factored into the program to accommodate the certification process.

9.2. Future Work

It is recommended that further research be conducted to understand how shared solar battery systems can be positioned as being more commercially attractive. Aside from residents, some of the most influential stakeholders in terms of shared solar-battery systems in strata becoming mainstream are the property developers themselves. If more of this type of development is to occur, it is vital that developers understand how installing these systems might offer them a commercial or market advantage. If we look solely at the NPV, then it seems these sort of projects are uneconomic. However, it is important to test what other factors are at play when developers are making investment decisions on whether to install solar-battery technologies.

For example, one of the biggest obstacles facing developers is securing planning approval. The design and planning approval process can be extremely onerous and is often subjective. Developers regularly have to adapt to ever-changing design specifications, energy ratings and homeowners' expectations around sustainability. It would be worth testing with the property development sector how they see solar-battery systems as a potential solution to planning approval challenges and whether there is scope for these systems enabling them to overcome compliance barriers. In particular, it would be interesting to test what the tipping point in terms of cost, apartment yield and return on investment would be.

To support the deployment of the governance model Australia-wide, further work has to be done in other states and territories particularly around community titling and rulings in relation to embedded network operators.

It may also be worthwhile testing developer's interest in P2P trading across the Western Power network, and what incentives could be provided to promote uptake of sustainable energy solutions.

The quantity of DER generation to be installed in the future could be estimated from the data given in section 6.5, however, currently the effects of this increased generation on the network are unknown. With storage increasingly becoming the preferred option, the spill back to the grid is likely to be minimised and therefore effects could expect to be smaller than for solar PV alone, however this requires further investigation.

10. References

Breadsell, J. (2019). *Domestic Practices and User Experiences Pre- and Post-Occupancy in a Low-Carbon Development.* (PhD). Curtin University, Retrieved from http://hdl.handle.net/20.500.11937/78566

Breadsell, J. K., Byrne, J. J., & Morrison, G. M. (2019a). Household Energy and Water Practices Change Post-Occupancy in an Australian Low-Carbon Development. *Sustainability, 11*(20), 5559. Retrieved from https://www.mdpi.com/2071-1050/11/20/5559

Breadsell, J. K., Byrne, J. J., & Morrison, G. M. (2019b). Pre- and Post-Occupancy Evaluation of Resident Motivations for and Experiences of Establishing a Home in a Low-Carbon Development. *Sustainability, 11*(14), 3970. Retrieved from https://www.mdpi.com/2071-1050/11/14/3970

Byrne, J., Law, A., hosking, R., Breadsell, J., Syed, M., Babaeff, T., . . . Newman, P. (2019). *Mainstreaming Low Carbon Residential Precincts: the WGV Living Laboratory*. Retrieved from https://apo.org.au/sites/default/files/resource-files/2019-09/apo-nid257016.pdf

Clean Energy Regulator. (2018). *The acceleration in renewables investment in 2018*. Retrieved from http://www.cleanenergyregulator.gov.au/DocumentAssets/Documents/The%20Renewable%20Energy%20Target%202018%20Administrative%20Report.pdf

Eggleston, J. (2020). *A Systematic Mapping Study on blockchain in distributed electricity: towards preventing the 'death spiral'*. Abstract accepted in Nature Energy. CUSP.

Hansen, P. (2020). *Optimising community energy: An institutional approach to the study of shared energy systems*. Submitted to Ecological Economics. Curtin University Sustainability Policy Institute.

Hansen, P., Morrison, G., Zaman, A., & Liu, X. (2020). Smart technology needs smarter management: Disentangling the dynamics of digitalism in the governance of shared solar energy in Australia.

Hoppmann, J., Volland, J., Schmidt, T. S., & Hoffmann, V. H. (2014). The economic viability of battery storage for residential solar photovoltaic systems – A review and a simulation model. *Renewable and Sustainable Energy Reviews, 39*, 1101-1118. doi:https://doi.org/10.1016/j.rser.2014.07.068

Western Australian Planning Commision. (2010). *Directions 2031 and beyond*. Retrieved from https://www.dplh.wa.gov.au/projects-and-initiatives/planning-for-the-future/directions-2031

Wiktorowicz, J., Babaeff, T., Breadsell, J., Byrne, J., Eggleston, J., & Newman, P. (2018). WGV: An Australian Urban Precinct Case Study to Demonstrate the 1.5 °C Agenda Including Multiple SDGs. *Urban Planning, 3*(2), 64-81. doi:10.17645/up.v3i2.1245

Wilkinson, S., Hojckova, K., Campbell, C., Morrison, G., & Sandén, B. (2020). Is peer-to-peer electricity trading empowering users? Evidence on motivations and roles in a prosumer business model trial in Australia.