

Here Comes the Sun

ARENA Project

How optimising the combination of rooftop solar and batteries can reduce cost, flatten demand and increase the deployment of renewable energy.

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MEFL is a not-for-profit organisation dedicated to sustainable energy that has been operating in Moreland since 2000. MEFL undertake community engagement, do research, consult, provide professional development and advocate on energy efficiency, renewable energy and related policy and planning issues.

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Executive Summary

The transformation of the electricity network is certainly now upon us. Years of environmental advocacy, rapid technology advances and shifts in consumer demand are driving an unprecedented shake up of our century-old supply network. With this change come opportunities (and some risks) to harness the value of renewable energy across the grid as we drive towards zero emissions.

Traditionally, Australia's electricity networks were largely built and controlled by state governments, and operated as central power supply systems managed with two policy imperatives in mind: security of supply and cost-effectiveness. The much-heralded disruption is turning this system upside down, bringing technical and financial challenges along with opportunities.

The big shift to date has been 'behind the meter', where there is a clear case for householders and businesses to invest in solar PV to avoid the cost of conventional energy supply. Yet establishing value 'in front of the meter'—sharing your locally generated energy across the grid—has so far been fraught.

Australia has the highest per capita rate of rooftop solar uptake internationally, at more than one in seven households (Clean Energy Council (CEC) 2014) and this trend is expected to continue. While the average size of solar PV systems has steadily increased in recent years (Australian PV Institute 2016), declining Feed-In-Tariffs and rebates mean households currently tend to size their solar system to match their maximum daily energy demand rather than their rooftop capacity. There is hence a substantial underutilisation of potential household rooftop solar capacity.

With the tapering off of feed-in-tariffs, owners of solar have been frustrated they don't receive a "fair" price for their home grown generation. On the other side of the fence, network operators have been concerned at the need to manage the technical impacts of solar PV and wind power to address the challenges of lower consumption.

Beyond the angst, new models such as microgrids and virtual power plants are starting to demonstrate that sharing solar PV generation and battery storage across the grid can leverage the opportunities and help manage the risks inherent in Australia's changing electricity sector. For customers, potential benefits include access to wholesale pricing and retail tariffs. For networks, there can be lower costs from local control and load management, particularly if the models can reduce peak demand and avoid the need for network infrastructure augmentation.

The key challenge for 'in front of the meter' solutions is not only to understand the technology, but also to apply the fundamental principles of supply and demand to determine where the greatest value can be realised.

To be of value, a successful microgrid, or other sharing arrangements, must also be able to achieve increased solar PV utilisation, reduce costs to consumers and/or

reduce or avoid infrastructure costs to utilities when compared with a business as usual approach.

The project investigated how sharing arrangements can result in:

- > more solar energy deployment than a business as usual scenario?
- > reduced cost per participating household? and
- > an optimised demand profile, in network terms?

To answer these questions, the project used a combination of energy demand profile modelling, financial cost-benefit modelling, consumer surveys, interviews and focus groups, logistical analysis, a legal, regulatory and policy review, and stakeholder consultation. The investigation considered the technical, financial, operational, market and policy/legal feasibility of microgrids and other energy sharing arrangements. To develop a successful business case each option was assessed against the following key factors: market – can the model attract customer engagement, technical – is the approach technically feasible, proven and low risk, financial – is there a clear financial benefit for participants, operational – are the arrangements to install, manage and maintain the systems realisable, policy – is the approach possible within the current regulatory framework and fair.

In partnership with GreenSync we developed a representative group of profiles that reflected common household demographics and the energy usage profiles that were common to the identified groups:

- > Single/Couple – Out during the day
- > Family #1 – Out during the day
- > Family #2 – Home during the day
- > Retiree – Home during the day

We clustered groups of five households based on an actual brownfield site in Northcote Victoria and assessed the potential for an integrated microgrid to achieve our objectives (more solar/less cost/flatten demand) compared to individual solar/battery roll out. The outcomes were compared against four scenarios: business as usual - where households do not share, network lead – where the existing networks are responsible for the management and installation of equipment, new entrant lead – where a third party (such as Reposit or a body corporate) manage the micro-grid, or where the project is financed and managed by a group of similarly minded individuals.

While each potential micro grid site will differ based on demographic and environmental factors and the model will vary according to the needs of the people and organisations involved there were some consistent results from the study.

Sharing solar PV generation and battery storage across a number of households has the potential to leverage the opportunities and help manage some of the risks inherent in the changing electricity sector.

While the benefit of shared infrastructure to each end user has been identified, in many cases projects are frustrated by the cost and regulations associated with transporting the energy across the grid.

Governance of micro-grid operations will need to be addressed as a crucial part of the offering with people preferring a third party led option for delivering power.

Projects need a competitive offering (i.e. better than an alternative), willing customers and the ability to operate effectively over time. A microgrid may not bring benefit if its capital and operating costs outweigh the savings, or if it can't attract customers.

To be viable, in front of the meter projects need to reflect the benefit to the network operator, not just the consumers. Costs and benefits vary from project to project, with the magnitude of network benefits in particular being highly sensitive to the state of the local network.

By storing excess energy and discharging it into the grid at a 'steadier' rate and at peak demand periods, micro-grids and batteries can assist network operators to manage technical issues associated with intermittency, voltage rise, voltage variability and peak demand, including unscheduled peak events.

Microgrids can provide benefits, such as reducing the total capital costs for households and utilities. This in turn can reduce both the sizing of distribution infrastructure (the poles and wires) and the costs associated with connecting to the broader network.

In areas of network constraint or where power supply quality is poor, microgrids and virtual power plants can provide network support by reducing total load on the network, or providing local generation or power quality services. In these situations, a project can benefit from reduced connection fees or service payments.

To meet the challenge of 100% renewable electricity supply, we will need to better coordinate supply and demand variability across the grid. Where there have been barriers in the past, new partnerships that link supply and demand benefits are emerging. These in front of the meter initiatives may well stem a grid defection trend and be a significant enabler of a decarbonised grid.

Introduction

The Here Comes the Sun project addresses the feasibility of integrated local electricity networks that incorporate battery storage and demand management¹ in existing residential suburbs. It evaluates the proposition that clusters of suburban houses sharing their electricity generated by PV systems and stored in batteries can produce better outcomes than each house operating independently and can result in reduced overall investment in both panels and batteries.

The project was undertaken by the Moreland Energy Foundation Ltd (MEFL) with partners Jemena, GreenSync Pty Ltd, and Little Sketches, and funding support by the Australian Renewable Energy Agency (ARENA).

Using a combination of energy demand profile modelling, financial cost-benefit modelling, consumer surveys, interviews and focus groups, logistical analysis, a legal, regulatory and policy review, and stakeholder consultation, the project investigated three key questions:

How can sharing arrangements result in:

- > more solar energy deployment than a business as usual scenario?
- > reduced cost per participating household? and
- > an optimised demand profile, in network terms?

To answer these questions, the project undertook modelling and considered the technical, financial, operational, market and policy/legal feasibility of microgrids and other energy sharing arrangements. The project approach is summarised in Figure 1 below.

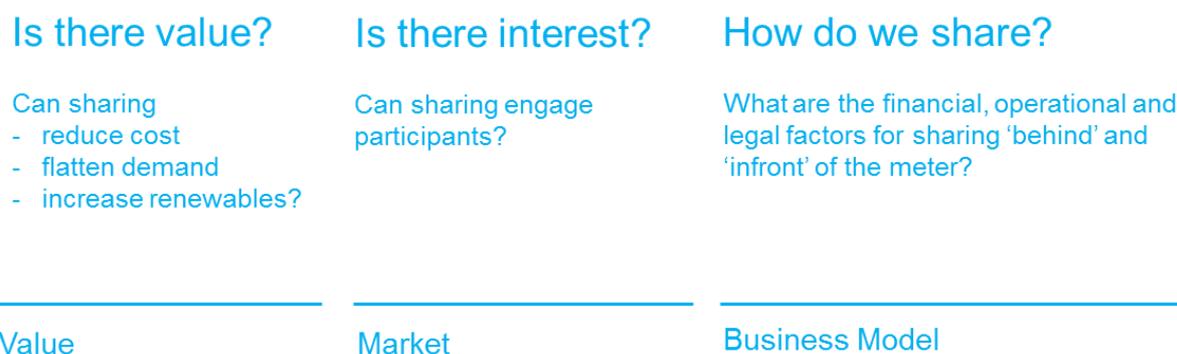


Figure 1 Project approach

¹ Remote switching of home appliances which consume large amounts of electricity, such as air conditioner units, pool pumps and electric water heaters.

Context

Traditionally, Australia's electricity networks have largely operated as central power supply systems managed with two main policy imperatives in mind: security of supply and cost-effectiveness (National Energy Market 1998). However in recent years a number of emerging disruptive changes are presenting significant opportunities and risks for governments, network operators, consumers and other sector stakeholders.

Climate change mitigation has arisen as a third key policy imperative for the electricity sector, resulting in renewable energy sources increasing to 15% of total generation in Australia in 2014 (Department of Industry and Science 2015). Further, over 1.51 million small-scale solar power systems were installed across the country by the end of 2015 (Clean Energy Council (CEC) 2016). However, there are technical considerations with regard to how many grid-connected solar panels individual households can install and how much solar power they can export to the grid at any one time. This is largely because Australia's networks were designed to facilitate power flowing in one direction - from the grid to customers.

Alongside these changes to supply, overall energy demand has declined due to energy efficiency and changes in Australia's industry profile, yet peak demand is increasing in certain circumstances due to population growth, weather and appliance use. Finally, a number of changes are occurring to the roles of retailers, consumers, network operators and other market participants. A range of innovative products, services and approaches are emerging, such as the rise of increasingly engaged consumers or 'prosumers' (consumers who are empowered by their choice to become more actively engaged in their electricity supply (CSIRO, 2014: 4)) electric vehicles (EVs), battery storage, smart meters and smart grids.

Sharing solar PV generation and battery storage across a number of households using a neighbourhood 'microgrid' or other energy sharing arrangements has the potential to leverage the emerging opportunities and help to manage the risks inherent in Australia's changing electricity sector.

Managing demand

Households have different patterns of energy use driven primarily by climate, the number of people in the household and their occupancy over the day, as well as the building design and the types and number of appliances in the home. This means that the total use of energy each day or each year, and the peak demand at any one time varies from household to household. To meet this demand, our homes are connected to a series of large power plants that deliver continuous energy through the 'electricity grid'.

The figures below demonstrate the average daily demand of a household and the aggregated demand of a group of households to show the overall energy usage profile that will need to be addressed.

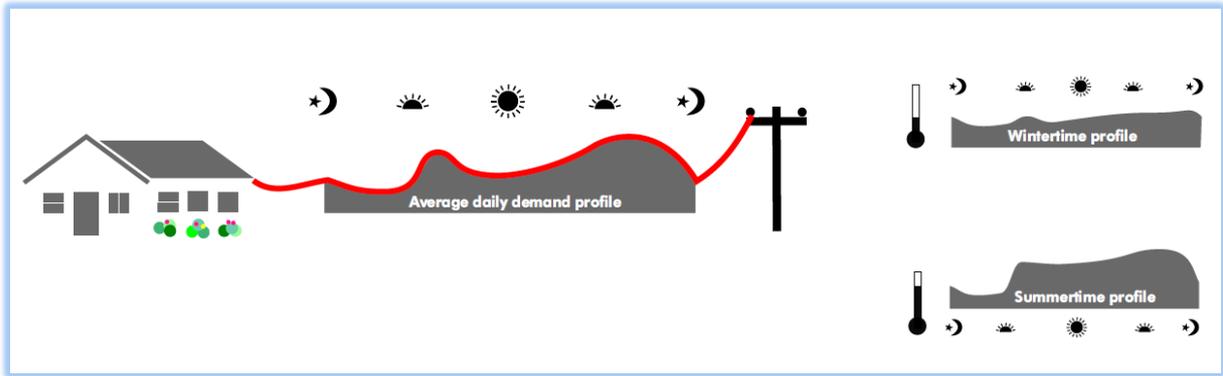


Figure 2 Energy demand from the grid varies with the time of day and the time of year.

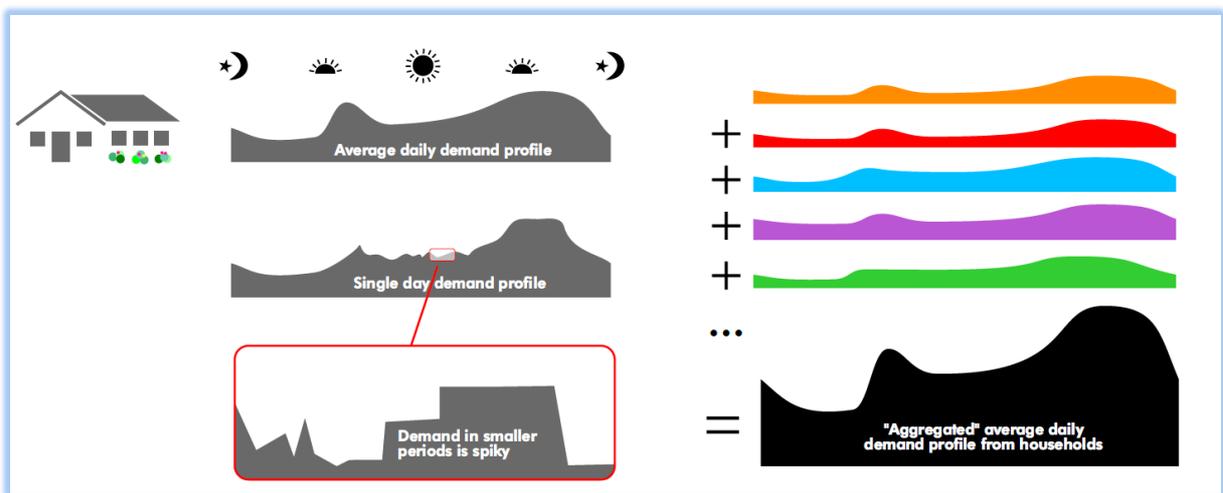


Figure 3 Aggregated demand is an average of different individual demand profiles

Demand is changing

The National Electricity Market (NEM)'s overall electricity demand has reduced 9% over the past six years, due to a decline in manufacturing and increased uptake of energy efficiency and solar PV (which affects consumers' demand for grid-supplied electricity) (Australian Energy Regulator, 2015). At the same time there has been significant growth in peak summer demand, due largely to the uptake of air-conditioning. Australia is likely to experience even peakier demand in the future as summers get hotter due to climate change. These trends are challenging the ability of traditional approaches - such as increasing peaking plant capacity and upgrading networks - to cost-effectively provide security of supply for these relatively short peak demand intervals. Difficulties in managing changing demand have led to concerns in recent years regarding over-investment in infrastructure ('gold-plating') and the potential of a 'death spiral' from rising network prices resulting in consumers turning to 'behind-the-meter' supply approaches. At the same time the public discussion is increasingly turning to considering pathways to achieve a more dynamic and customer focused network.

Supply is changing

Renewable energy sources had increased to 15% of total generation in Australia in 2014 (Department of Industry and Science 2015). Australia's renewable energy uptake in recent years has been dominated by small scale solar, principally household (or rooftop) solar PV, which comprises 15.3% of renewable energy sources (Clean Energy Council 2014: 7). Australia has the highest per capita rate of rooftop solar uptake internationally, at more than one in seven households (Clean Energy Council (CEC) 2014) and this trend is expected to continue. While the average size of solar PV systems has steadily increased in recent years (Australian PV Institute 2016), declining Feed-In-Tariffs² and rebates mean households currently tend to size their solar system to match their maximum daily energy demand rather than their rooftop capacity³. There is hence a substantial underutilisation of potential household rooftop solar capacity.

Balancing supply and demand

Whether considering large-scale solar and wind farms or distributed rooftop solar, different energy sources can create technical challenges for network operators to maintain a smooth and reliable electricity supply (ARENA 2015). Although not insurmountable, the intermittent nature of solar and wind power impact the 'second-to-second balance between total electric supply and demand' of traditional networks, which have very minimal capacity to store excess energy or compensate for gaps in supply (Fares 2015; Reedman 2012).

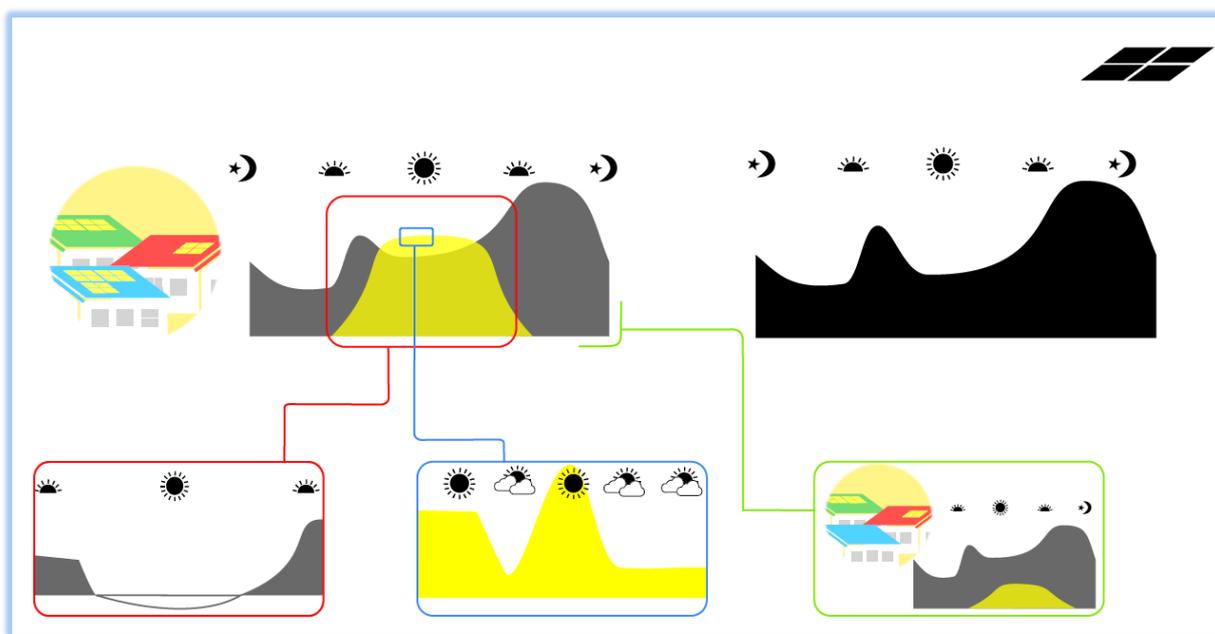


Figure 4 Potential peaks and troughs of solar power

Figure 4 shows the minute to minute changes in solar generation that can affect the “balance” in the grid. A normal sunny day (red) will generate consistent output, intermittent cloud cover (blue) will cause minute to minute peaks in generation that will need to be compensated for by the grid, there is also the change in generation

² For example, the current Victorian Feed-In-Tariff for solar is 5 c/kWh, well below the retail price for electricity (~25 c/kWh).

³ Sizing is also determined by physical factors such as roof size, orientation and shading.

throughout the day (green) which creates different outputs depending on the time of day and time of year. Greater levels of solar power being added to the grid may result in greater imbalance in the grid. Batteries, managed properly, could be a way to smooth the current peaks in solar output.

In addition, the existing grid was designed to transport power from central generators to households; 'reverse power flow' from distributed solar to the grid leads to voltage regulation issues and can create potential safety risks (NREL 2008; ARENA 2014). There is also the risk that without appropriate network planning and control, batteries could increase rather than reduce unplanned and peak demand (for example, through households charging electric vehicles during an early evening peak). Network operators are concerned about the maintenance implications of the increased intensity of wire use associated with distributed generation (John 2013). In some locations, feeding in excess solar power has been restricted or prevented, with the result that the consumer receives little or no value for their generation.

However in some instances such as where the network is constrained there is value in encouraging solar generation to reduce the need for network upgrades or the events of power outages. This has been trialled on Bruny Island (ARENA 2016) and proven successful in reducing grid demand.

Storage is emerging as a key enabler

Battery storage has recently attracted considerable media attention because of the number of potential benefits it might provide to households, network operators and other stakeholders. For example, batteries can allow households to store excess energy generated by their solar PV during the day for use at night and during periods of lower solar production (e.g. in overcast weather). New lithium ion batteries have relatively higher energy capacity, longer life cycle and are more robust compared to traditional lead-acid batteries (Anyphapharadorn et al. 2014). Further, it is generally considered that developments in battery technology efficiency and effectiveness can be expected to continue in the short and medium terms.

By storing excess energy and discharging it into the grid at a 'steadier' rate and at peak demand periods, batteries can assist network operators to manage the technical issues associated with intermittency (Mossoba et al. 2012; Zipp 2013), voltage-rise and voltage variability (Gortz 2015; AusNet Services 2016), and peak demand (Clean Energy Council (CEC) 2014), including unscheduled peak events (Leadbetter and Swan 2012). Batteries can also provide power in the event of a network outage (AusNet Services 2016). A recent three year battery trial in 10 Victorian homes by AusNet Services, a Victorian network operator, found networks could save up to \$3,000 per household over five years (AusNet Services 2016), with the greatest value available in network constrained areas that would otherwise require investment in infrastructure. Combined with network augmentation and control, batteries can fundamentally address security of supply issues that are associated with rooftop solar.

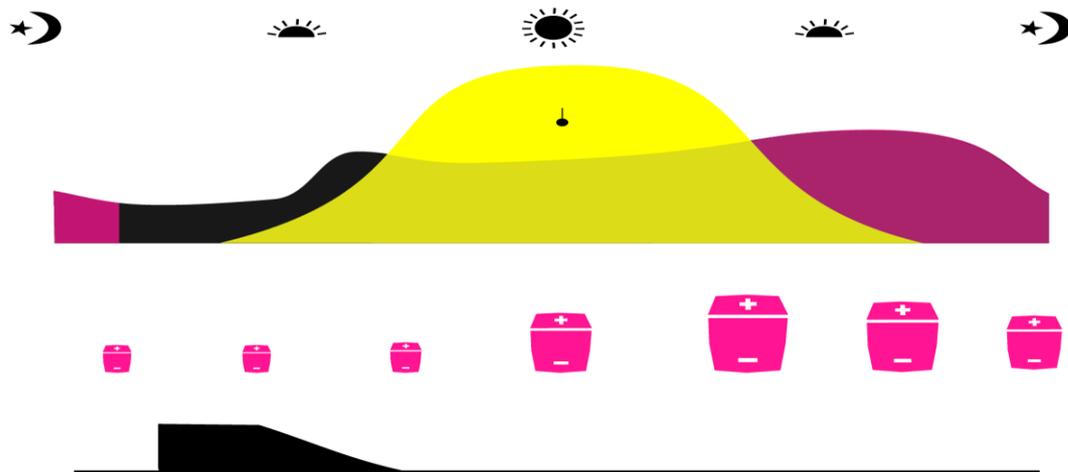


Figure 5 Battery charging cycle

The figure above depicts the charge and discharge patterns of a standard battery. The important issue is the reduced demand on the grid in the evenings when grid demand is often at its peak. This allows for better managed peaks and a reduced dependence on peaking power plants which would in turn reduce cost to the network.

Furthermore, a recent study indicates that batteries could save a typical Victorian household \$1,500 over five years (AusNet Services 2016). Batteries enable households to use more of their solar energy ‘behind the meter’ and offset their demand for grid-connected electricity, which can be three to five times more expensive than standard solar export tariffs (Australian Energy Market Operator (AEMO) 2015). Similarly, they may incentivise households to add generation capacity to existing systems or to purchase larger new systems. Batteries also give households the potential to withhold excess energy and sell it into the grid at peak (higher price) periods; a practice known as ‘energy arbitrage’.

Sharing can help balance

Sharing solar PV generation and battery storage across a number of households has the potential to leverage the opportunities, and help manage the risks, inherent in the changing electricity sector. Sharing can help sidestep network limits to distributed renewable energy (DRE) and allow residential (and other) customers to generate, store and use more of their own solar PV generation. Moreover, the ability to reduce peak demand through sharing could actively assist network utilities to manage challenging periods of variable power production and overall activity on the grid. Sharing solar generation and battery storage infrastructure can also provide other benefits, such as reducing the total capital costs for households and utilities, and enabling participating households to sell electricity into the grid at higher peak prices and charge their batteries during off-peak (lower price) periods.

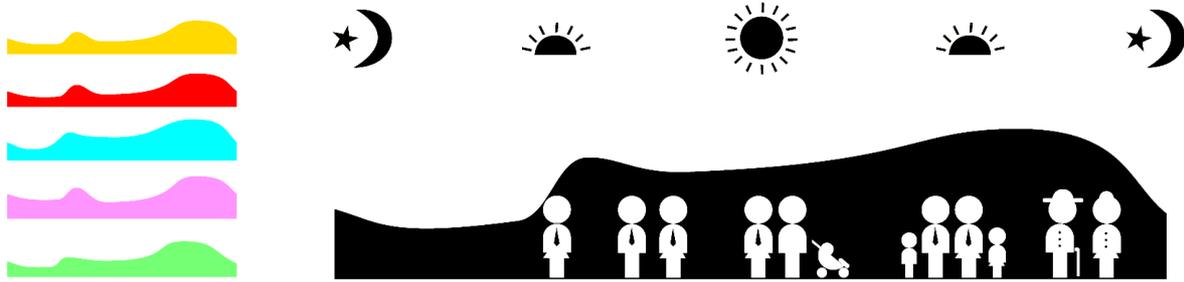


Figure 6 Aggregated demand

Figure 6 (above) depicts the reduced peaks and flatter demand resultant from sharing energy generation and use across a group of people with diverse energy use patterns.

Microgrids are one way to enable solar PV and battery storage sharing. Microgrids are small scale private local electric power grids or networks with the capacity to be controlled and coordinated (US Department of Energy 2014). As with other grids, they consist of distribution (e.g. electrical cabling), electricity generation and grid regulation, however in microgrids, generation (e.g. solar) occurs close to consumption. They hence enable the sharing of power between houses, businesses (e.g. in shopping centres) or apartments. Microgrids may operate 'behind-the-meter', sometimes sharing fewer (or just single) connections to the main grid (e.g. caravan parks) or alternatively can be 'off-grid', that is operate independently of the main grid (e.g. in remote areas or on military bases and islands). They can also involve sharing electrical infrastructure, such as multiple individual batteries or one (or more) common batteries.

Finally, an alternative way of sharing distributed renewable energy (DRE), known as a virtual power plant (VPP), uses software to actively coordinate generation and consumption between non-neighbouring houses. Virtual power plants (and related concepts such as 'local energy trading') are starting to demonstrate that sharing solar PV generation and battery storage across the grid can work to leverage the opportunities and help manage the risks inherent in Australia's changing electricity sector. For customers, potential benefits include access to wholesale pricing and retail tariffs. For networks, there can be lower costs from local control and load management, particularly if the models can reduce peak demand and avoid the need for network infrastructure augmentation. Of course, the value of sharing locally generated energy across the grid is dependent on the time of day, the time of year and the location. The key challenge for 'in front of the meter' solutions is not only to understand the technology, but also to apply the fundamental principles of supply and demand to determine where the greatest value can be realised.

Within this context, the Here Comes the Sun project addresses the feasibility of integrated local electricity networks that incorporate battery storage and demand management⁴ in existing residential suburbs. It evaluates the proposition that clusters of suburban houses sharing their electricity generated by PV systems and stored in batteries can produce better outcomes than each house operating independently and can result in reduced overall investment in both panels and batteries.

⁴ Remote switching of home appliances which consume large amounts of electricity, such as air conditioner units, pool pumps and electric water heaters.

How might we share?

There is a range of technology and business model combinations that are emerging with the aim of capturing value from implementing shared solar and battery storage arrangements. There is also a range of stakeholders driving development and deployment; diverse stakeholders with different driving principles and incentives.

Microgrid delivery options

While the technical and financial benefit of energy sharing can be established in terms of microgrid and VPPs generally, and layout and equipment decisions are site dependant, the feasibility of energy sharing (whether 'behind the meter' or 'in front of the meter') depends on the delivery model. Through a stakeholder consultation workshop with representatives of residential consumers (MEFL), demand managers (GreenSync), a distribution network provider (Jemena) and government (ARENA), a range of different options were identified under which a residential microgrid of neighbouring households could potentially occur.

Community led

A group of households that choose to deploy a microgrid configuration so that their energy supply needs are primarily or wholly sourced from the microgrid. This could occur in an existing area or in a green-field site and might involve a connection to the network or isolation from the existing grid (stand-alone).

Network led

In this option the network provider makes network and/or non-network changes to stimulate and disburse energy from microgrids. This might take the form of the utility collecting and redistributing energy locally via a large local battery or coordinated demand management at the household level (such as remotely switching appliances on and off). Network led approaches change the nature of the customer-utility relationship and has the capacity for large scale improvements to the operation of the public grid. There are a number of current and recent research and pilot projects on this model. See table 1 (Page 17)

The maintenance of the utility network is a challenge given its size. It is not known how sharing can reduce the maintenance burden of the network since even in a mini-grid design as introduced above, the network is central to the transmission of power.

The challenge with any reduction in maintenance or redundancy is not arbitrarily noisy power supply but large failures at peak network use times when equipment is overloaded. Certainly deploying more DRE systems results in lower demand, and it is hoped DRE can move peak demand and suppress instantaneous peaks so that network size and maintenance are reduced.

Network providers are highly trained and well positioned to support any critical DRE systems and so permit more reliance on DRE. If a utility installs a DM or DG system then it is well placed to support such a system and reduce any training burden on the

homeowner. This may also apply to mini-grids and microgrids if they become prevalent and essential infrastructure.

New market entrant led

Under this option the market and regulatory system allows electricity to be traded to encourage households to generate more electricity and consume less energy. A new market entrant manages and controls the shared resource on behalf of households, for example by creating a system of credits or Local Electricity Trading (virtual net metering). Participating households recoup money from their investments and can be incentivised to adopt energy efficient behaviours such as switching off their lights when not in use. Software is a common feature of these approaches, and some solutions also involve hardware installed near consumer devices in order to switch them on and off⁵ via Wi-Fi. Virtual sharing technologies mean households need not be contiguous.

While the microgrid sector is relatively immature (albeit rapidly evolving), there are several key characteristics that provide fundamental differentiation between microgrid models. The characteristics revolve around key aspects such as: relationship to the main grid; ownership; operational control; and the objectives and incentives of the primary stakeholders driving each different microgrid deployment.

Driving principle/s: Are the key design and operating principles of the microgrid primarily designed to create value for participating households or businesses, the network operator or a third party stakeholder, such as a property developer or a technology company. The incentives of the principal stakeholder will inform the business model and the technologies deployed.

For example, if a microgrid is being designed, financed and deployed by a group of contiguous householders seeking sustainable, affordable and independent energy supply and that are seeking to minimise (or eliminate) their reliance on grid supplied electricity, their business model and microgrid configuration may be significantly different to a microgrid established by a distribution business seeking to manage local demand or avoid the need to invest in augmenting the existing grid. Alternatively, a property developer may be incentivised by the prospect of owning and operating generation, storage and grid infrastructure in a new housing development. They might also seek to have an ongoing role in the retailing of energy to households, or they may seek to transfer this function to another party.

Grid connection: Will the microgrid system be connected to the main grid or be stand-alone? In new developments (greenfield) and probably at the edge of grid, it may be financially rational to create a stand-alone microgrid without a connection to the main network. In another context, existing households serviced by the existing main grid in current settlements (brownfield) may be driven by dissatisfaction with existing service arrangements and to aspire to disconnect from the existing grid and invest in stand-alone infrastructure. Fundamentally though, is it intended that the microgrid will maintain or establish an operational connection to the main grid, or will the microgrid be separate from the main grid with no connection?

Ownership and operation: Who will own and/or operate the microgrid system?

⁵ For example, Sensibo <https://www.sensibo.com/>

In general these issues are addressed by individual consumers (possibly a third party) and do not affect other entities until the power generated is available for sale at the meter. In front of the meter addresses the ability to sell electricity, the rules and regulations around selling electricity from a microgrid, insurance and the impact on the grid.

What's currently happening?

Across Australia and around the world a number of approaches are being considered, developed and pioneered. While emerging approaches involving distributed generation, batteries and microgrids can contribute to a more resilient, clean, competitive and cost-effective network, "...facilitating the widespread take up of these technologies smoothly, fairly and efficiently is a massive challenge for the industry, governments and consumers alike" (AusNet Services 2016a). Microgrid approaches are maturing rapidly (AusNet Services 2016b) and there are a number of trials and studies underway by industry, government and the community; some examples are summarised in Table 1.

Table 1 Existing trial and studies

Project	Location	Brief description	Reference/s (author date)
Mooroolbark mini-grid project (AusNet Services with GreenSync)	Mooroolbark, Vic	One year trial from April 2016 of 14 houses with solar, purpose built 10kWh battery for each home. Fully distributed mini-grid, with each house having its own solar and battery system.	Ausnet Services and Greensync, April, 2016 – read more at www.greensync.com.au/mooroolbark-community-mini-grid/
Brooklyn microgrid	Brooklyn, U.S	A microgrid scheme being planned for a low-income neighbourhood (Red Hook) which could provide up to 10 MW. The microgrid will utilise both commercial and residential generation sources such as solar power.	LO3 Energy, 2016 – read more at http://brooklynmicrogrid.com/
Alkimos Beach project	Alkimos Beach, WA	1.1 MWh+ battery and energy smart packages in at least 100 homes with solar PV. The microgrid has the option of connecting homes with a back-to-back converter so residents have more control over their energy.	ScienceNetwork WA, April 2016 – read more at http://www.sciencewa.net.au/topics/energy/item/4146-going-off-grid-easier-with-friends#k2Container
Reposit Power virtual power plant trial by Reposit Power, University of Sydney, University of Tasmania, and the Australian National University	Bruny Island, Tasmania	Trial of GridCredits automated energy trading software with 40 solar and battery households to enable energy arbitrage. The software is designed to integrate with the wholesale energy market and markets for network support and ancillary services. The project will research the ideal sizing of solar and storage systems, how much	http://arena.gov.au/project/consumer-energy-systems-providing-cost-effective-grid-support-consort/

		households should be paid, and through what mechanism	
Haiti Microgrid Project	Les Angalis, Haiti	Earthspark International has completed the first of 80 microgrids in Haiti. This microgrid connects 430 homes and businesses with a 400 kWh battery powered by 93 kilowatts of solar PV panels. The goal is to construct a total of 80 microgrids by 2020.	http://microgridknowledge.com/quick-microgrid-news-haiti-microgrids-ny-prize-congress/
Solar Microgrids in Nepal	Okhaldhunga and Khotang, Nepal	A combined capacity of 35 kW of battery storage will provide power for 540 people who live in some of the poorest regions of the world. The microgrid is powered by solar and has significantly reduced the electricity costs for its users. The use of solar has also reduced CO2 emissions by 41 tonnes per year.	Cara Goman, March 2016 – read more at http://microgridknowledge.com/solar-microgrids/

There remains, however, a need for a clear and shared understanding of the myriad of complex and rapidly developing technical, financial, operational, market and policy factors involved. This is particularly the case for brownfield applications, which have received limited attention to date despite comprising the vast majority of Australian housing.

Is there value?

To be of value, a successful microgrid, or other sharing arrangements, must be able to achieve increased solar PV utilisation, reduce costs to consumers and/or reduce or avoid infrastructure costs to utilities when compared with a business as usual approach.

In order to better understand the circumstances under which the benefits might be realised and the conditions under which benefits might be maximised, representative clusters of neighbouring households characteristic of residential Australia were modelled to compare the relative benefits of sharing their solar and batteries versus not sharing.

Profiles

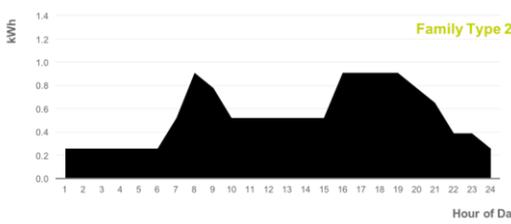
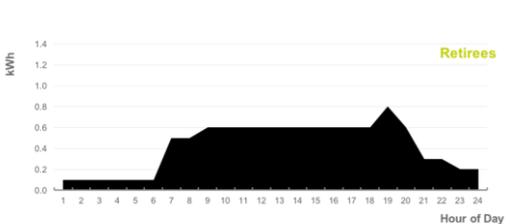
The clusters comprise combinations of four characteristic household types that are representative of key segments of the Australian household mix and are consistent across the modelled configurations. The household clusters allow modelling to help identify the key factors in profiles that determine individual and aggregate results when considering the outcomes of sharing solar PV and batteries.

The four household types include:

- **Single/Couple:** Small household, at work during the day
- **Family Type 1:** Large household, at work/school during the day
- **Family Type 2:** Large household, at home during the day
- **Retirees:** Small household, at home during the day

Table 2 Household types

Household type	Characteristics	Profile
<p>Single/Couple:</p> <p>Small household, at work during the day</p>	<p>Low daytime demand, evening peak</p> <p>Limited benefit from solar within current tariff structure</p> <p>Battery storage would enable storage of generation for evening use</p> <p>May have siting opportunity for more solar and batteries</p>	
<p>Family Type 1:</p> <p>Large household, at work/school during the day</p>	<p>Low daytime demand on weekdays, evening peak</p> <p>Limited benefit from solar, though weekend daytime use improves utilisation</p> <p>Battery would enable storage of generation for evening use</p> <p>May have significant siting opportunity for more solar and batteries in larger size dwelling</p>	

<p>Family Type 2:</p> <p>Large household, at home during the day</p>	<p>Daytime demand on weekdays, increasing during weekends Strong benefit from solar Battery would enable storage of generation to meet evening use May have additional capacity for solar even where existing installation is large</p>	
<p>Retirees:</p> <p>Small household, at home during the day</p>	<p>Daytime demand throughout the week Strong benefit from solar Limited utilisation of battery to manage on-site use May have additional capacity for solar even where existing installation is large</p>	

Scenarios

Three scenarios were adopted to compare the benefits of using solar PV and battery storage in individual households, or as a shared asset amongst a group of neighbouring households, to increase solar PV utilisation, reduce costs to consumers and/or reduce or avoid network infrastructure costs.

‘Business as Usual’ Baseline

The ‘business as usual’ (BAU) scenario seeks to set a reference for the current and projected uptake of solar PV and battery storage by individual households. In general, BAU is currently driven by the ‘behind the meter’ benefit due to the current low value for exported energy and is constrained by the local network capacity to cope with electricity inflow. The sizing of PV and storage are seen as typical for each household profile based on existing installs.

Shared Energy

The ‘shared energy’ scenario seeks to explore the potential of utilising energy generation and storage for the combined benefit of a group of households. This scenario responds to the fact that household energy use profiles differ and that excess generation on one household may be made available for use by a nearby household with higher demand, thus avoiding the need to import more energy from the wider network. The households in this scenario use the same sizing of PV and storage as in the BAU scenario, though the equipment is aggregated as a central plant.

Shared Energy & Demand Management

The ‘shared energy and demand management’ scenario seeks to explore the additional benefit derived through managing peak demand or peak solar export for the benefit of the network. The scenario responds to the fact that household demand and PV generation can be simultaneous (reducing the level of input to the grid) and without coordination can impact the overall capacity of the network to guarantee

supply. The scenario again use the same sizing of PV and storage aggregated as a central plant or virtual power plant.

Variables

The following key variables were considered for each configuration to understand the sensitivity to each characteristic.

Energy Use

The amount of energy (kWh) used by a household in any one day or year is dependent on factors such as climate, the number of residents and their occupancy patterns, the building design and the use/type of appliances. The usage profiles are characteristic of the amount of energy that the different household types use based on the actual energy use of similar profiles derived from smart meter data provided to MEFL.

Peak Demand

The peak demand is the maximum power (kW) drawn in any one day across the year. Typically, the combined or coincident residential peak is higher in the evening when most household types are at home. A critical peak is the highest peak across the year and is an important factor for determining the network capacity required to service an area and for future infrastructure planning. Across Australia the critical peak is increasingly associated with a summer peak that is in turn associated with air-conditioning use during very hot days. The usage profiles are characteristic of the demand different household types draw.

Solar PV Generation

Annual solar PV generation (kWh p.a.) is determined by the system size and the geographic location. Solar generation over the year will vary according to the season, for example summer output in temperate climates can be more than fivefold that of winter months. The solar generation profiles used allow evaluation of annual average output of energy and monthly peak generation to identify the capacity to meet peak demand and manage export constraints during periods of low generation such as winter.

Battery Storage Characteristics

Battery storage characteristics are complex due to the non-linear nature of their chemistry. The key factors for modelling are the usable capacity of the battery (kWh) taking into account; the depth of discharge, the rate the battery can be charged and discharged to respond to a situation, and the 'round trip' efficiency which accounts for losses in energy conversion. These factors were modelled as being consistent rather than modelling specific and varied battery characteristics.

Modelling results

The following is a summary of the impact that sharing solar PV and battery storage has on combined energy import (kWh) and overall peak demand (kW) on the network for following scenarios.

- Sharing solar only
- Sharing solar and storage
- Managing peak demand
- Maximising solar

Sharing solar only

When just solar PV is installed on households sized to benefit ‘behind the meter’, without battery storage, the following is observed:

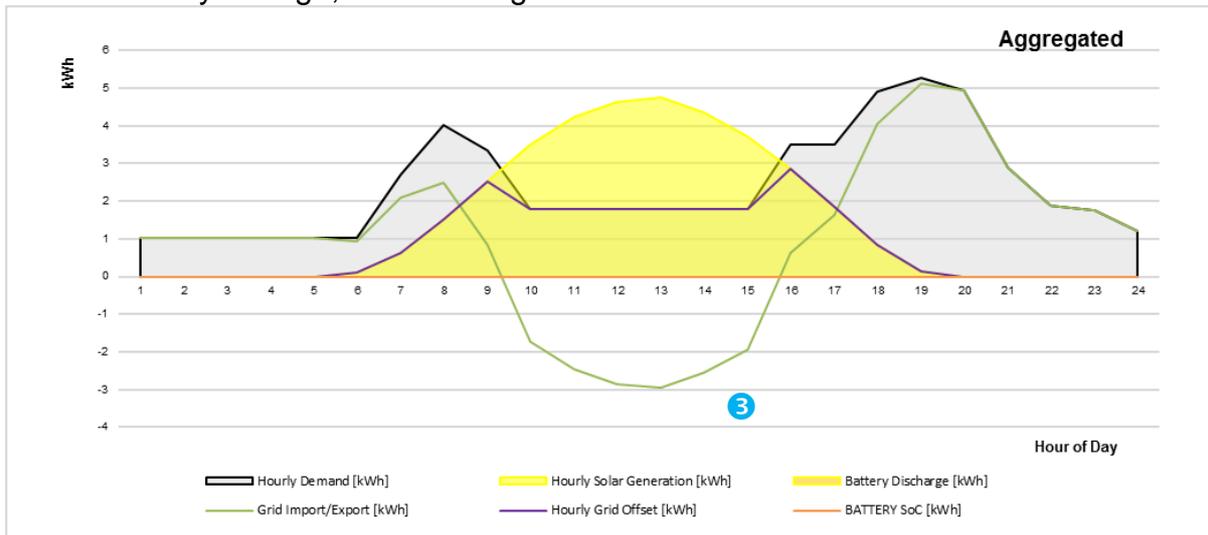


Figure 7 Profile for solar without storage

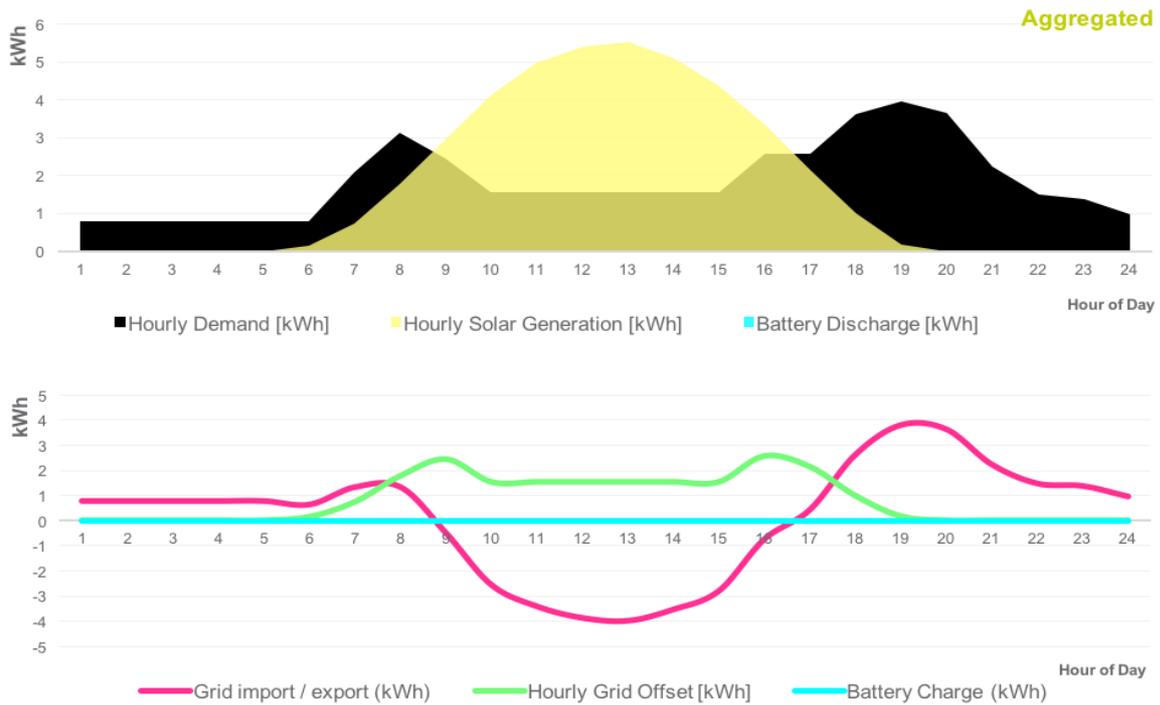


Figure 8 Profile for solar with storage

1 4

1. Solar by itself achieves only marginal reductions in the overall peak demand from the network, as the peak remains in the evening which is generally outside of the PV generation envelope.
2. Solar generation sees a significant reduction in the volume of energy imported from the network; a 40% reduction in energy imported in this modelled outcome.
3. Solar generation is exporting for a key part of the day with an average peak export at 60% of the peak import.
4. No differentiation in network impact between scenarios.

When the same amount of solar PV is instead installed on houses with low daytime load the impact in peak demand and energy imported and exported from a network perspective is the same. In the 'business as usual' configuration there is a variance in the energy import and export metered and billed at the residential level. In a 'shared energy' configuration residents are able to access the financial benefits of locally generation being locally utilised.

- ✓ **Solar PV Utilisation** Excess solar generation can be utilised by neighbouring homes
- ✓ **Consumer Costs** Neighbours sharing their solar can avoid importing more expensive energy
- ✗ **Infrastructure Costs** The same infrastructure is required to meet peak demand and winter demand.

Sharing solar and storage

When solar PV is combined with battery storage there is a greater opportunity to store energy for later use and hence reduce the overall peak.

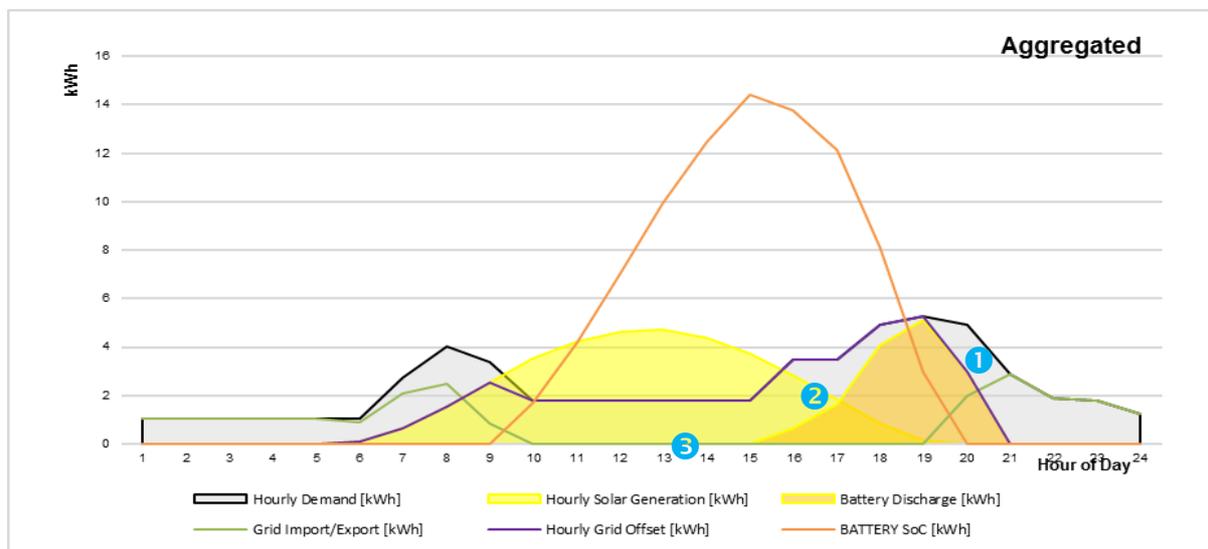


Figure 9 Shared solar and battery storage

Figure 9 depicts the aggregated profile of the modelled houses with solar and battery storage.

1. Solar combined with battery storage can achieve a significant reduction in the overall peak demand from the network; about 45% for the modelled outcome as the storage shifts PV generation to reduce the evening peak.
2. Solar combined with battery storage sees a further reduction in the volume of energy imported from the network; a 60% reduction in energy imported.
3. In this scenario, battery storage has also eliminated solar export to the grid allowing its value to be realised by reducing imported energy and avoiding any potential issues associated with exporting to the network.

Again, when solar PV and battery storage is installed on houses with low daytime load the impact on peak demand and energy imported and exported from the network perspective is the same. In a 'business as usual' scenario individual homes can avoid energy importing if they are able to locate and appropriately size equipment for their load. In the 'shared energy' scenario neighbours can also benefit from combined PV generation and battery storage.

- ✓ **Solar PV Utilisation** Excess solar generation can be stored and utilised by neighbouring homes
- ✓ **Consumer Costs** Neighbours sharing their solar can avoid importing more expensive energy
- ✓ **Infrastructure Costs** Less infrastructure is required to meet peak demand.

Managing peak demand

When solar PV and battery storage are coordinated across multiple households there is greater opportunity to manage demand at peak times such as during a summer heatwave.

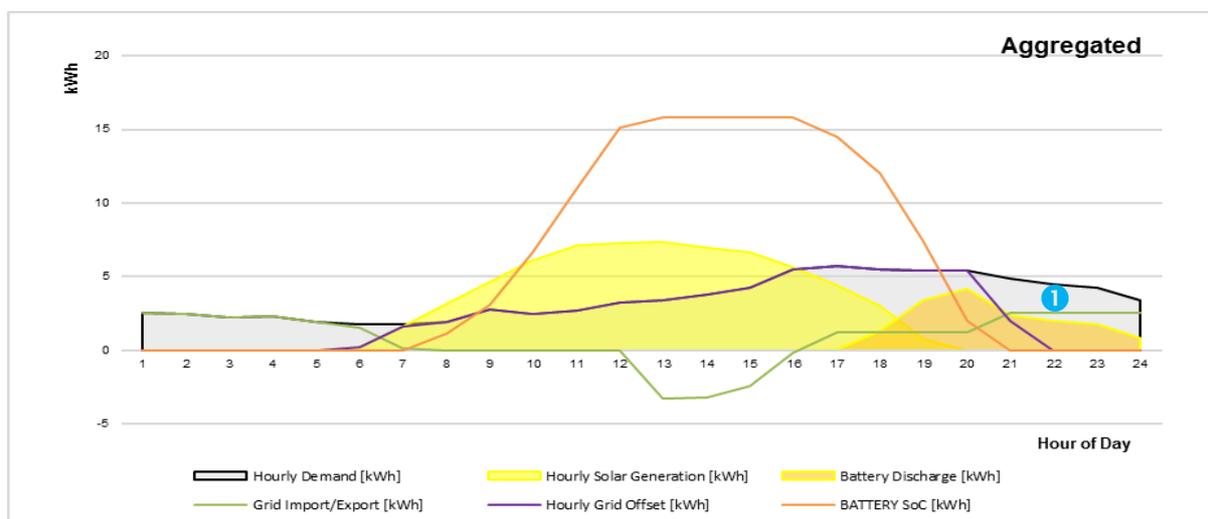


Figure 10 Solar and sharing combined with demand management

Figure 10 depicts the aggregated profile of the modelled houses with solar and battery storage as well as an energy management system.

1. When coordinated, the 'shared energy and demand management' scenario can further reduce a maximum peak event to benefit the broader network.

The 'business as usual' scenario can perform reasonably well if there is appropriate matching of individual solar and battery units to each household. When uncoordinated, a 'shared energy' only scenario could have a higher critical peak as storage in this scenario discharges rapidly when there is no solar generation to avoid import. This results in the battery depleting by mid evening and calling on the network to supply the late evening peak.

When solar PV and battery storage can be managed and optimised the maximum combined demand from the network during critical peak times can be limited. This has potentially significant benefits in avoiding the requirement for infrastructure augmentation in network constrained areas and managing peak loads to reduce the level of blackouts caused by excessive demand in peak times such as hot afternoons in summer.

- ✓ **Solar PV Utilisation** Excess solar generation can be stored and utilised by neighbouring homes
- ✓ **Consumer Costs** Neighbours sharing their solar can avoid importing energy at more expensive times
- ✓✓ **Infrastructure Costs** Less infrastructure is required to meet critical peak demand on network.

Maximising solar

When solar PV and battery storage are coordinated across multiple households there is a greater opportunity to increase solar PV generation for shared use.

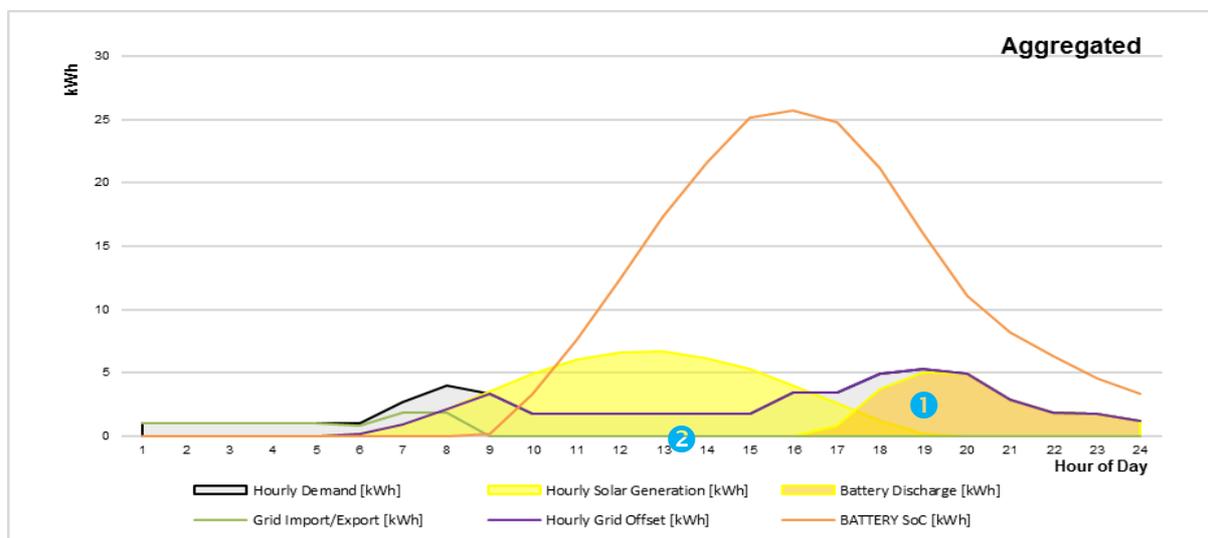


Figure 11 Increased levels of solar generation through additional panels

Figure 11 shows the possible levels of generation if additional solar is added to roof space that is currently not being used (due to systems being sized to only cover household usage) allowing for additional export of battery charging.

1. By increasing solar PV by 40% on the 'business as usual' sizing (modest given available roof space) and battery storage by 50%, at least 80% of annual net energy needs can be met locally.
2. Where combined as a shared energy' configuration the scenario can avoid exporting any solar PV generation to the grid. Thus avoiding low feed in tariffs and any broader network issues.

Allocation of solar remains conservative and rooftop surveying indicates potential for much higher utilisation.

- ✓✓ **Solar PV Utilisation** Excess solar generation can be stored and utilised by neighbouring homes to take advantage of available roof-space
- ✓? **Consumer Costs** Neighbours sharing their solar can avoid importing more expensive energy, though need to weigh up against capital investment
- ✓✓ **Infrastructure Costs** Less infrastructure is required to meet annual demand on network.

What are the cost considerations?

Introduction

The aim of the financial evaluation is to understand the significant costs and revenues that determine value and identify key factors that may inform viable business models.

Costs

There are a number of capital costs and operating costs associated with microgrids and each will have an impact on the overall financial viability of a particular scheme which will in-turn influence the ownership and operating structure of the scheme.

Capital costs

Capital investment costs are a key consideration for both households and utilities alike. The equipment required to generate, transport and store electricity has an upfront cost that needs to be balanced with the capacity to recover benefit over time.

Solar PV

Solar PV has dramatically reduced in cost, falling from \$6 to \$1.50 per watt in the last decade. The technology is mature and has no moving parts or other factors that would increase the risk of failure. While there is some degradation in performance over time, it's routinely considered to have at least a 25-year serviceable life and hence long warranty periods.

Cost : ~\$1.50/W installed (including inverter)

Influences : Scale, suitability of roof space.

Battery

Battery technology has rapidly advanced in the last 10 years, driven initially by electronics such as mobile phones and laptops and now by electric vehicles and the potential for grid connected electricity storage. There are a range of battery chemistries such as lead-acid, lithium ion, zinc-bromide, each with varying characteristics and at different stages of maturity in the market. Overall, at an average of \$300/kWh, battery storage has not yet reached a price viable for mass uptake in the residential market. However, there is growing consensus from market analysts that \$100kWh or lower will be reached within the next five years.

Cost : ~\$300/kWh installed (may require replacement inverter)

Influences : Scale and timing of project, charge and discharge profile required.

Control Systems

Control systems such as inverters are required to rectify current and voltage to meet service requirements, avoid equipment damage and ensure health and safety. Standard inverter technology is advanced though there are costs in enabling battery storage to be retrofitted to existing solar PV systems and enabled for grid-side control to provide network support.

Cost : ~% of total cost

Influences : Complexity and heterogeneity of microgrid

Networking Infrastructure

Network infrastructure is required to reticulate electricity across a microgrid. Within a brownfield site, a project may be able to utilise existing infrastructure. For a greenfield site the infrastructure may already be incorporated into the capital cost.

Cost : Variable

Influences : Ability to utilise existing infrastructure or embed in new development cost envelope

Operating costs

Operations

Once installed most equipment has limited requirements for operational control. Most, if not all operating requirements, can be achieved through automation and software control. Therefore, there are minimal labour costs though software licencing may be incurred as an operational cost.

Cost : variable

Influences : Level of automation/software control and complexity of conditions

Maintenance

Solar PV has proven to have a low maintenance and fail rate requiring replacement. Battery technology is considered to have similar characteristics though predictions of life expectancy/fail rate are harder due to its immaturity and variables on charge and discharge use. Overall the combined technologies are forecast to have low maintenance requirements and straightforward replacement where failure occurs.

Cost : ~% of total cost

Influences : Quality of equipment and installation

Administrative

Administrative costs arise from metering and billing of electricity, servicing of capital finance and related activities. Administrative activities may be taken on by an existing electricity utility such as a retailer or distribution network operator, a broker or body corporate entity.

Cost : ~% of total cost

Influences : Ability to utilise existing or scalable systems and processes

Income/revenue:

Solar load shifting

Solar load shifting is the action of storing excess PV generation during the daytime for use when demand is higher such as in the evening. This is seen as the key driver of battery uptake in residential markets to best take advantage of on-site generation for use in peak times. Residential customers in Victoria pay between 20-40 cents per kWh for electricity purchased from the grid and receive between 5-7 cents per kWh for solar electricity fed into the grid. The opportunity to use storage to shift this electricity to meet load can be quite significant in better utilising solar generation and further expanding its uptake.

Key Drivers : Retail (Volumetric) Peak Tariff/ Export Feed-In Tariff differential
Revenue : ~\$0.20/kWh/day,
Suitability : Viable across all sites, building and business types where there is an evening load profile

Tariff arbitrage

Tariff arbitrage is the action of charging up the battery with off-peak electricity and discharging it during peak times to take advantage of the tariff differential.

Key Drivers : Retail (Volumetric) Tariff Peak/Off-peak differential
Revenue : \$/kWh
Suitability : Viable across all sites, requires

Peak demand management

Building and maintaining the network to meet peak demand is relatively costly, and so has a significant influence on networks capital expenditure program and ultimately on network prices. Demand and peak demand charges are common in medium and large businesses though are a new concept for residential customers. Cost-reflective pricing is increasingly being considered in jurisdictions due to the increase in critical peaks associated with residential use such as air-conditioning pushing system capacity. The introduction of smart metering to measure 'time of use' enables a greater capacity to monitor energy use in peak times and charge a customer. Battery storage presents a key opportunity to avoid peak demand charges by avoiding grid import.

Key Drivers : Peak/Critical Peak/Maximum Peak Tariff
Revenue : \$/kWh
Suitability : Viable across all sites where times of use/critical peak tariffs are available

Wholesale price response

There is a variation through each day in the wholesale price of electricity. Individual sites or microgrids can be configured to increase the volume of electricity drawn from the grid when wholesale prices are low and reduce draw when prices are high. The wholesale price for a half hour period can range from \$25 to \$300 MWh. This requires forecasting software to predict wholesale price paths and battery specifications that allow discharge at a sufficient rate to capture value and whilst retaining capacity to service other needs.

Key Drivers : Differential between the average high and low wholesale spot price
Revenue : \$/kWh
Suitability : Viable across all sites, requires retailer participation

Network response

Individual sites or microgrids can be configured to provide response to distribution network constraint, enabling the network operator to reduce capital investment in network infrastructure. An example is where individual sites or microgrids may enable island mode and avoid drawing from the grid to avoid over capacity demand during a critical peak event such as a heatwave.

Key Drivers : Likelihood and frequency of capacity constraint and value of demand response

Revenue : \$/kW

Suitability : Viable across sites within a network constraint

Here Comes the Sun

Understanding the costs and benefits for combining and sharing rooftop solar and batteries

Models for sharing energy

We consider four potential models for integrated local electricity networks to share energy from rooftop solar and incorporate battery storage. The configuration of these models depends on two key factors:

1. Whether the system is
 - a. purely sharing energy, or;
 2. designed and controlled to take advantage of demand management benefits from existing network.

11. Whether households are connected together
 - a. physically, 'behind the meter' (e.g. in a microgrid or embedded network,) or;
 - b. virtually, 'in front of the meter'.

No sharing
In the base case households do not share rooftop solar or batteries.

Each household chooses a system that

minimises the import of energy on their own demand profile.

Example: Existing uptake of residential solar PV.

1. Shared energy

In the shared energy case household solar and batteries are connected either (a) physically or (b) virtually through the existing network. The aim is to optimise energy use to meet a shared need responding to energy market prices at different times of the day or year.

Households are physically connected to their own microgrid that operates 'behind the meter'.

Optimisation responds to the import cost.

Example: greenfield development sites.

a

Households enter

arrangements with an individual partner or aggregator through a retailer to share energy using the existing network.

Examples: Virtual Net Metering (VNM), Reposit Power, and Mojo Power.

a

Households are physically connected to their own microgrid that operates 'behind the meter'.

Optimisation responds to the state of the network, as well as the import cost.

Example: Ausnet Mooroolbark mini-grid.

b

Households enter

arrangements with a retailer or aggregator to share energy using the existing network, and respond to network conditions.

Example: United Energy Mornington Peninsula Project, Energen Residential A/C DRED

Costs and benefits

The value for all shared energy models is made up of a series of system costs (for capital and operations) and benefits from reduced energy delivery and network costs.



Costs and benefits vary between each model. Key factors are:

- > Network benefits in particular are highly sensitive to the 'state' of the local network.
- > Administering arrangements between participants increase overhead costs.
- > Whether the capital costs are 'marginal' (i.e. if infrastructure was going to be built anyway).

The relative costs and benefits are grouped into benefits, operating costs and capital costs. Gradient shading is used to show the indicative range or uncertainty in costs and benefits.

Sharing introduces more cost and benefits to consider

Benefits: Solar load shift, tariff arbitrage and wholesale price response.



Costs: Upright capital for solar and batteries.

Benefits: Solar load shift, tariff arbitrage and wholesale price response.



Costs: Upright capital for solar and batteries, network infrastructure, control systems and all operating costs.

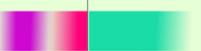
Benefits: Solar load shift, tariff arbitrage and wholesale price response.



Costs: Upright capital for solar and batteries, control systems and some operating costs.

Demand management introduces more benefits for the network

Benefits: Solar load shift, tariff arbitrage, wholesale price response, network response and peak demand management



Costs: Upright capital for solar and batteries, network infrastructure, control systems and all operating costs.

Benefits: Solar load shift, tariff arbitrage, wholesale price response, network response and peak demand management



Costs: Upright capital for solar and batteries, control systems and some operating costs.

Is there interest?

Market Assessment

For any microgrid or sharing arrangement to be taken up, options must meet the needs of the households and other market participants. Ideally, they should:

- > represent a simple and clear value proposition
- > cost households the same or less than households purchasing solar and batteries individually
- > involve a reasonably simple process, including access to affordable finance
- > provide tangible incentives for network operators, retailers, developers and/or new market entrants to invest in, manage and market a microgrid option
- > be able to use, leverage or develop channels to reach interested markets.

This section considers levels of interest in each microgrid option and sharing more generally using the results of a survey, interviews, a focus group and stakeholder consultation.

What is the market feasibility of sharing?

A useful framework for considering the potential uptake of new applications of technology is the diffusion of innovation bell curve⁶. Rogers (2003) proposes that the spread of a new idea or innovation is influenced by factors such as the innovation itself, communication channels, time, and the social system within which it is being deployed. As illustrated in Figure 12 below, Rogers contends that innovations are taken up progressively through distinct groups of consumers: innovators, early adopters; early majority; late majority; and laggards.

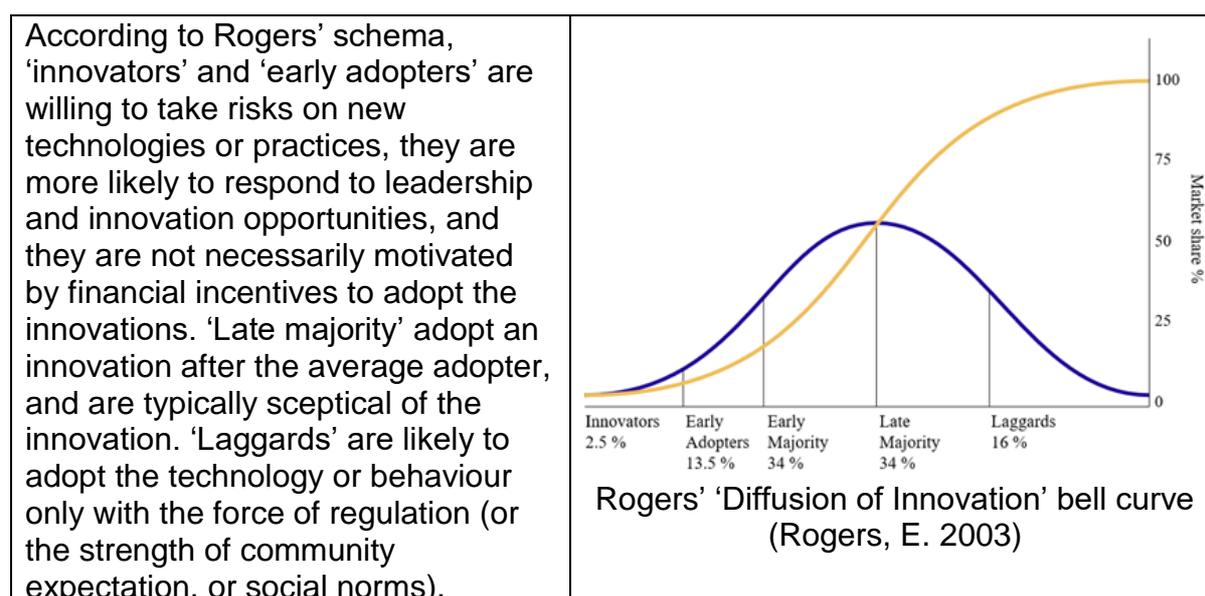


Figure 12 Diffusion of innovation curve

The level of uptake of a target innovation will inform the type of mechanism selected to drive its further uptake: for example, where a technology or behaviour has been adopted by less than 15% of the population, programs should target innovators and

⁶ Developed and popularised by Everett Rogers in his book Diffusion of Innovations, first published in 1962

early adopters, and program design should focus particularly on the types of mechanisms to which these groups will respond.

Overall, the market research undertaken in this project (and by others) indicates a number of ‘innovator’, ‘early adopter’, and potentially some ‘early majority’ households, with an interest in sharing arrangements. As with the early stages of rooftop solar, however, it is important to distinguish between a household’s cited aspirations and motivations and the likely rate and timing of uptake by them. For example, although interested and supportive many are waiting for battery costs to decrease or want more information and/or would prefer for network businesses to lead, before they act. From another perspective, nearly a third of survey respondents appear to be indifferent to the method of electricity delivery to their home. These sorts of results suggest that moving beyond niche ‘innovators’ and ‘retail protestors’ to broader markets will ultimately rely on the extent to which the sharing option is cheaper, better and/or easier than conventional options.

Market assessment methods

To understand the interest, drivers and constraints influencing households’ potential participation in each of the microgrid options, a survey of 107 households in Victoria was undertaken regarding:

- > general interest in and understanding of key microgrid concepts
- > perceptions of costs and benefits
- > attitudes towards sharing, privacy and allocation of responsibility, and
- > impacts on their dwelling/land and associated risks.

In addition, six households in inner northern Melbourne were recruited for interviews and a focus group to further explore consumers’ understanding of the risks and impacts associated with microgrids. Innovator, early adopter and early majority households (see figure 12) were deliberately targeted in this project because they were considered the most likely initial market for microgrids. The self-selecting nature of project participation further refined this group to those likely to be interested. To balance this targeted research with an understanding of the broader population, a review of key market research by other organisations was undertaken to inform the project survey and focus group. Finally, consultation with representatives of network operators and new market entrants throughout the project explored their particular market drivers.

The concept: desirable but not necessarily simple

Market research undertaken in this project indicated that microgrids and other ways of sharing solar and batteries appeal to a substantial proportion of what could be classified as ‘innovator’, ‘early adopter’ and potentially even ‘early majority’ households. Nearly half of surveyed households agreed (45%) and a further 15% strongly agreed that they would like to take part in a scheme where they share their battery space and solar power. As one commented, they were “open to various technological and economic options pending more details of pros/cons”. In terms of an on-grid microgrid option, 31% were ‘interested’ and a further 10% ‘strongly interested’. These households were more likely to be motivated by the potential for price security and cost sharing.

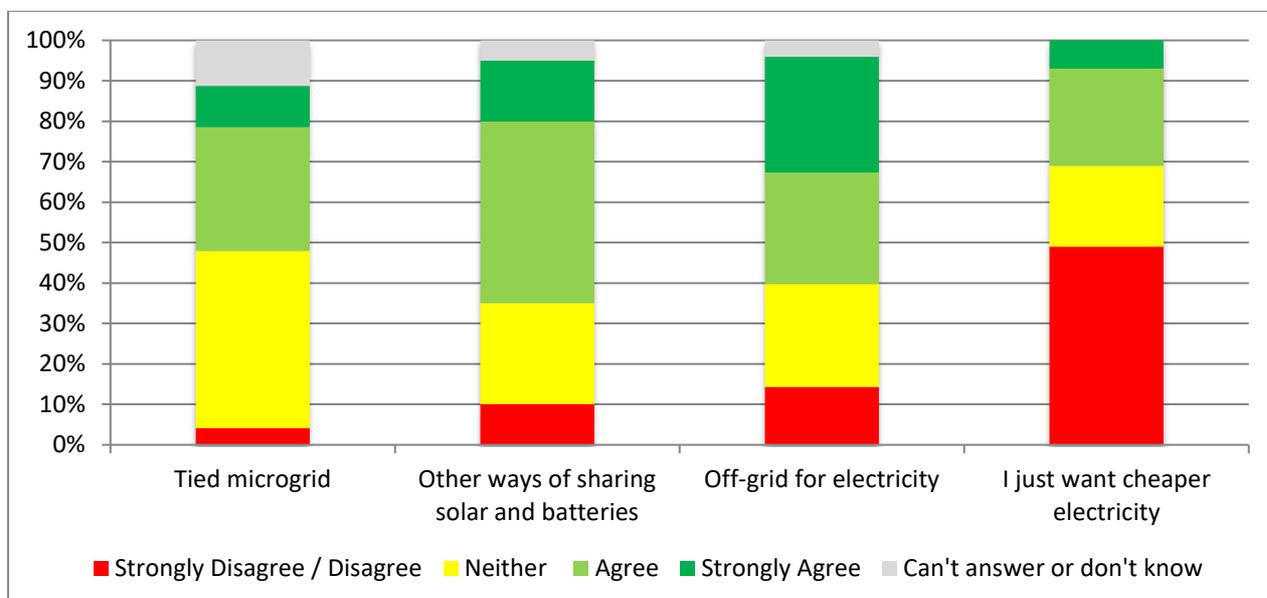


Figure 13 Household desire for various microgrid options

Figure 13: Households’ appetite for tied microgrids, other ways of sharing and off-grid options, and levels of indifference to networking arrangements

Households also expressed a considerable appetite for disconnecting from the grid (Figure 13), not just for electricity (59%) but for all utilities (39%). Unsurprisingly, energy independence was an important motivation for these households. As one commented, “I would like to be independent of the system where I have little control over my costs”. This interest in disconnecting from the grid is considered largely aspirational since the majority of survey respondents lived in the inner or outer suburbs where disconnection is less practical. Indeed, the focus group exploring microgrid concepts in greater detail with a real-life cluster of six households found all wanted to remain grid-connected. Furthermore, 37% of households surveyed recognised and felt concerned that households disconnecting from the grid would leave others to pay more to maintain the grid.

Despite households’ positive attitudes to different sharing options, it is important not to overstate their level of interest. Nearly a third of all survey respondents (31%) agreed or strongly agreed that they ‘just want cheaper electricity, I don’t care how it arrives’ (Figure 13), suggesting ambivalent engagement with the microgrid concept or possible ‘energy fatigue’. These households were also typically willing to buy renewable energy only if it was cheaper (33% of all households) and to remain connected to the electricity grid. Furthermore, the interviews and focus groups indicated that households did not have a strong understanding of sharing and related concepts, particularly on-grid microgrids (Figure 13).

Households’ motivations for taking up batteries and other new technologies such as microgrids were (in order of importance) ‘environmental factors’ (88% of households), ‘energy independence’ (86%), ‘cost sharing’ (70%) and ‘price security’ (63%) (Figure 14). These factors were also reflected in the focus group. Environmental motivations are not surprising, given survey respondents’ GreenPower uptake (43%) was several times the national. In terms of desire for greater independence and control of their energy, a link could be discerned between households’ energy empowerment and renewable technology uptake. Over a third of

survey respondents (36%) felt they successfully managed their energy bills and were satisfied with how much they paid and such households tended to have larger PV arrays. Similarly, focus group participants appeared not to be intimidated by the technical requirements of sharing their electricity.

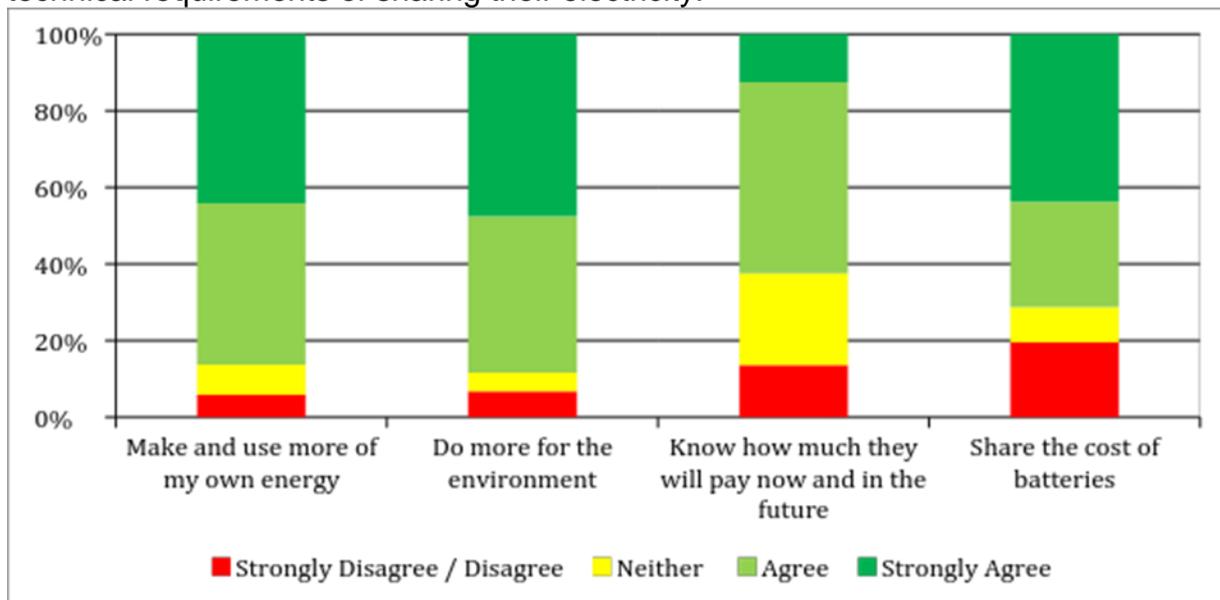


Figure 14 Household motivations for using batteries and other technologies.

Costing less to share is but one of many cost factors

While nearly a fifth of households disagreed or strongly disagreed that cost sharing was a motivation for them, cost sharing was important to the majority (70%) of households (Figure 14). However these households reported a complex range of cost-related considerations, including price security (63%) and a willingness to pay more for renewable energy (41%). Other considerations included pay-back period, potential for savings through community bulk procurement, tariff implications (with over 28% of households on a high (over 15 cents per kWh) solar feed-in tariff) and perceptions of reduced battery cost into the future. In addition, the interviewees and focus group participants indicated a willingness to pay more for a house already on a microgrid and were comfortable with potential contractual obligations, but were unwilling to extend their mortgages.

With regard to battery cost trends, more than a quarter of households (29%) intended to purchase batteries in the near future, whereas about half (53%) intended to 'wait and see what happens with costs'. As one household noted, "battery technology will improve over the next 5 years so it might be too early to invest in purchasing batteries that could be outdated in a few years". The relatively strong appetite for batteries is not surprising since over half (55%) of the survey households already had solar PV; much higher than the national rate of 16.5% (UNSW, 2016). Moreover, 3% already owned a battery and three quarters (75%) knew of, or had read about battery storage, while a further 11% indicated that they were already familiar with the technology.

Is it easy and accessible? Not yet.

Because of the complex and varied concerns around microgrids and sharing, 42% of households surveyed felt the utility should lead investment in batteries and other solar technologies. Such households preferred to remain connected to the grid and could be considered more likely to be 'early majority' adopters rather than 'innovators', or possibly those who felt they had already invested 'enough' in energy solutions.

In general, to be attractive, not only should sharing cost less than individual purchases, it must be accessible in terms of finance, information and be underpinned by a clear, simple process. In terms of household payment preferences, 'financed purchase' was the most popular method (42%), followed by up-front payment (35%), and then paying a fee indefinitely (16%). The popularity of the first two approaches is consistent with most PV installations in Australia being owned by the householder. Arrangements such as in most power purchase agreements (PPAs) have not proven popular for solar in Australia - potentially due to lack of trust in retailers or the lack of evident ownership of the assets.

The interviews and the focus group provide interesting insights into the range of financial and operational factors and risks a household might need to consider (depending on the option). They preferred a body corporate model and were satisfied with an excess payment scheme for electricity use over an 'agreed capacity' approach. Also, while willing to recruit neighbours to a Consumer (DIY) microgrid arrangement, these households preferred separate meters and to not know each other's electricity use, and expressed concern about maintaining good relationships. Finally, they asked questions about logistical arrangements, safety risks around roofs' weight bearing capacity and electro-magnetic radiation, housing the battery/s, allocating costs and benefits between landlords and tenants (as well as tenancy exit rights), and the need for a private easement.

Comments from survey respondents reflected these themes, for example:

I want to use solar and the best technologies for clean energy but I am not wealthy. I need help navigating options relative to cost.

Shared seems perfect, but there would probably be problems with neighbours. It would help if they were approached by you [a broker or service provider], not us.

I am concerned that if anything goes wrong I will be left high and dry. When my solar inverter failed I was amazed at the level of lack of customer awareness and reluctance to solve MY problem I experienced from everyone involved.

Having a clear understanding of how it will work and the risks involved.

Drivers for other market participants

There two distinct sets of drivers and market considerations for other market participants. Network operators can materially benefit from facilitating sharing, particularly in network constrained areas, as they can use additional solar and storage capacity to manage peak demand, voltage and intermittency issues. Retailers are driven to provide customers with new services that can reduce their bills and increase their price security, and can draw on their existing channels.

Apartment and shopping centre developers already factor embedded network infrastructure administration and costs into their developments; Finally, new market entrants such as Reposit can take advantage of emerging business opportunities, but will need finance and market channels.

In general there is a strong interest in pursuing solar and battery storage with environment and cost motivations and incentives. Punters are concerned at the complexity and risk and there are too many unknowns at the moment.

What are the logistical considerations?

Logistical considerations encompass operational requirements including the arrangements to install, manage and maintain a microgrid system. Key aspects include safety, reliability, ownership, equipment requirements and maintenance, amongst others.

They also include legal and regulatory considerations. Fundamentally, some approaches may not even be possible within the current regulatory framework, while others will test existing arrangements governing the generation, distribution and retailing of energy.

Having already considered some of the technical, energy and financial considerations of energy sharing in previous sections of this report, this section turns to the logistics and considerations associated with the operation of microgrid systems. It first compares the layout and equipment requirements of 'business as usual' systems and of different microgrid configurations. This section then examines some of the logistical, safety, and ownership implications that are relevant to this project.

The operational feasibility of energy sharing solutions is affected by a range of factors, including:

- Layout and equipment: configuration of solar PV, battery storage, control and wiring
- Logistics: organisation and implementation
- Safety: what risks exist for households and the network?
- Ownership: how can system procurement and access be apportioned?

Layout and equipment

The layout and equipment requirements of microgrids are heavily dependent upon factors associated with the households who are planning to share power. A green field site such as an apartment complex can wire each apartment into the grid at the time of construction overcoming many of the obstacles that face brown field sites. A common existing form of a microgrid is the embedded network style that is already in use in some apartments and commercial complexes.

Brown field sites may be constrained by proximity to other houses who want to form the microgrid, access to channels to link the houses via private wire and the availability of space to place a central battery.

Real life cluster design exercise

In order to determine potential site layout constraints, availability of existing technology, and many other variables, designs for a potential working system entirely from commercial components were considered for a set of six 1925 era houses in Northcote, Victoria. While this was not undertaken to determine the simplest, cheapest or an otherwise optimal system, it served to illustrate that existing

commercial microgrid technology is available and requires no customisations for an urban microgrid with central plant, and the exercise revealed various logistical considerations discussed here.

Configurations

The microgrids considered in this section primarily involve variants of a 'private wire' arrangement to connect participating households. In addition to household-level technical installations and wiring changes that occur regardless of the sharing arrangement, there are three key design choices:

1. The location of the battery/s and energy management system (EMS) control; either distributed or centralised.
2. The connection to the main grid/public network, with options for a single interconnector or multiple interconnectors.
3. Approaches to wiring the houses in the microgrid to allow sharing and coordination.

In this context, depending of the nature of the land title, a system may be interconnected on common land (for strata title arrangements) while in private title situations the system may traverse private titles and/or public land.

A microgrid with distributed systems and control will allow participating houses to draw power directly and then pass on any excess power. A house drawing more power than its solar system supplies would also draw back through the central EMS. A microgrid with central storage and a single interconnection to the main grid would have one central EMS to manage the grid connection. In this configuration houses have to retain an indirect connection to the grid. For an urban microgrid that has a single interconnector to the main grid and is readily accessible for servicing, a relatively simpler and more economically sized battery system is possible.

In terms of control, drawing from a local PV array and from the grid is already the established arrangement via a bi-directional meter, and a similar device could be deployed for a microgrid. In this instance the household generates PV power and the control system returns as much of this as needed to the house. When there is excess power, the management system would divert PV power to the microgrid. When the household needs power and does not have PV power, the EMS would draw from the microgrid and in the absence of excess power available to the microgrid, could switch to the public utility.

A microgrid with multiple interconnectors would have a central EMS in addition to an EMS for each house to manage the grid connection. As these items are expensive, each retained grid connection would be retained at considerable cost.

In general, microgrids would benefit from the use of micro-inverters on each solar panel, where the DC electricity generated by the panel is immediately inverted to AC and synchronised with a 240VAC circuit. While a failing panel or inverter could still short such a circuit, the reduction in energy produced would be limited to the faulty panel (not impacting power generation from the rest of the array). In addition, micro-inverters have the capacity to communicate with other systems and a panel-by-panel performance report would be available, removing the need to de-rack the entire string for fault finding. While multiple micro-inverters would generally cost more compared with a single centralised inverter, the distributed nature of solar PV in

suburban microgrids would benefit from this. Furthermore, they micro-inverters have a much lower failure rate⁷ and are projected to last considerably longer than central inverters⁸.

The operational obligations for consumer microgrids will depend on whether the microgrid is owned under a PPA or leasing arrangement (owned by a third party) or it is owned by a strata body corporate or private titles homeowners.

While third party ownership may cost more ultimately (since the third party business needs to derive profit), all PPA and lease arrangements see the lessor support and repair the distributed renewable energy (DRE) equipment which may well be preferable to the participating lessees. However, the main obstacle to a microgrid being provided under a PPA is that a homeowner who is not using their agreed minimum draw would expect this energy to be diverted to others on the network. However, even if this occurs, the PPA would require the householder to pay for this energy as is the case with individual DRE systems under a PPA. Homeowners attracted to the concept of economic sharing may be put off by paying whether energy is shared or not.

Under a lease, microgrid homeowners would each pay a fixed fee. If the homeowners collectively purchase the DRE equipment and do not involve a third party then they must use an energy management system or a site manager system to record power generation and imported grid power.

Each house on the microgrid could be metered and billed for its half-hourly power draw (a variable use record) or it could be metered only to enforce billing an agreed maximum daily draw (capacity based). In general, it would be desirable that ownership of the system is in proportion to estimated household demand. This then would set a maximum capacity for each house and would provide these advantages:

1. It is private – there need be no observation of energy usage patterns on a house to house basis for consumption within the agreed maximum.
2. It is logically aligned with the purchased share. If a house anticipates drawing 10% of the system capacity (of, say 120kWh), it can agree to a kWh value directly proportional to this (such as 12kWh).
3. The risk of excessive use is reduced. If cheap or free power is available as an “unlimited” (or very inexpensive metered cost), then there is a risk that where any occupant may consume the shared resource more than they need on the assumption that others will take it if they do not, or that the resource may go to waste (a ‘tragedy of the commons’ scenario). If there is a maximum draw for a household, over which they are billed for grid import, then the household is obliged to be more careful with energy demand and use.
4. Enforcing an agreed limit would allow for simpler management of the performance of the system. If all occupants agree to a fixed capacity, then the decision to upgrade the system capacity can rest simply on the aggregated use exceeding the current capacity. In a variable demand scheme, the system has to be kept larger than the highest total of all demand. As above, if shared DRE energy is very inexpensive, but also uncapped, then demand could climb unchecked.

⁷ For example, up to 10x reduced MTBF http://www2.enphase.com/wp-uploads/enphase.com/2011/03/Enphase_WhitePaper_Reliability_of_Enphase_Micro-inverters.pdf page

⁸ <https://matter2energy.wordpress.com/2013/05/01/microinverter-update/>

5. Those who do not use the power they have agreed to will not have comparative use data to compare with others and so the desirability of any kind of refund is likely to be lessened. That is, if the system use were treated as a commodity per kWh of generation, then it is likely that homeowners away on holidays or otherwise not using the system might be inclined to add up the value of the energy they have not used. This is less likely if each household consumes up to a limit, but without a record.
6. Being aware of a ceiling on demand will bring about more restraint on energy consumption. This is because exceeding this ceiling is conceived as an exceptional event with consequences⁹ while incremental use allows increasing demand without any disproportionate penalties. This situation and incentive was observed in other areas where different penalties cause unexpected incentives¹⁰.

In contrast to shared DRE with simple agreed consumption limits, it is likely that a homeowner with their own separate DRE system may consume more power on the assumption of making best use of the battery and the daytime energy it has captured. Since stored energy will vary from day to day, it is more effort for the homeowner to monitor when the battery energy is spent, since this will be different each day. It is likely that established patterns of energy use will empty the energy storage system and result in grid imported energy, unnoticed.

Safety

Home solar is a relatively safe technology. Installation standards mandate array cut-off switches and isolation circuits for the inverter so that the risks of electrocution, fire or exporting when the grid is down are removed. The risks associated with concentrating energy in batteries include overheating and failure. Perhaps the only indicator of this risk in Australia for house-mounted lithium batteries is that the maximum specified operating temperature was 40 degrees Celsius for one large brand. This may be too low for many Australian sites, and safety software installed in batteries means they are likely to shut down several times a year if 40 degrees is the operating temperature limit.

Maintenance

Solar arrays are made for low maintenance or no maintenance operation and are provided with no scheduled maintenance. The homeowner is shown how to observe the equipment and to report if the equipment is not performing, within warranty. Many new battery systems have only ten-year warranties and so it is more likely the entire battery module is swapped out rather than maintained. If a home DRE system is not performing, this may be visible to the new market provider who may be observing trends, and also to the homeowner who may see their PV production or storage problems graphed on their phone. This is likely to see a fault serviced quickly.

The EMS, micro-inverters and house meters could all be accessed remotely. This remote access means that the microgrid houses can choose to have a third party monitor all systems. The remote service can, depending on the agreement, access

⁹ Such as a social contract, for example <http://plato.stanford.edu/entries/contractarianism-contemporary/>

¹⁰ For example <http://freakonomics.com/2013/10/23/what-makes-people-do-what-they-do/>

and adjust the system or it could merely email and SMS the microgrid houses. The EMS can provide a mobile telephone connection to reach the owners or the central control service in case the public utility or the internet connection is down, for example.

Ownership arrangements

How owners may own the plant ranges from a situation where the plant is entirely shared and central, to where the plant components are distributed and owned individually and only the generated energy is shared. In either case, some sort of sharing arrangement would be at play and this could take the forms of sharing with a private group contract or sharing with the system documented as a shared service under control of a Body Corporate (or Owners Corporation).

Ownership could take the form of all title or unit holders owning a proportion of the system or a third party owning the system and providing it as leased or in a PPA arrangement. As mentioned previously, land title (whether strata or privately owned) also has implications for microgrid deployment and operation.

Some permutations of unit ownership include:

1. A homeowner owns their own PVs and shares metered excess power with the scheme.
2. A homeowner owns a proportion of all PVs and power from PVs on their roof is pooled centrally then metered when it is consumed.
3. A homeowner owns their own battery and allows metered capacity and charge in the battery to be used by the scheme.
4. A homeowner owns a proportion of a central battery and their use is an agreed fixed value (such as an amount per day or a proportion of the total battery capacity).

The incentives associated with these potential configurations would have implications for managing system sharing and cooperation amongst owners, for example conflict resolution (or conflict avoidance).

In terms of insurance requirements, the PVs and inverters in microgrid schemes are likely to be covered by existing home and content insurance¹¹. However the issue of a microgrid and co-owned or shared products falls outside the current scope of home insurance. Separate insurance would need to be sourced to insure the microgrid. Insurance options and costs will vary with size, type and layout of microgrid.

Legal considerations

Microgrid proposals will be impacted by the law in differing ways, depending upon the way in which the microgrid is intended to be implemented:

¹¹ A summary is given here

http://www.homeimprovementpages.com.au/article/your_guide_to_solar_panel_insurance with non-binding inclusion in this article <https://www.allianz.com.au/home-insurance/news/the-benefits-of-solar-power>

1. At the infrastructure level (electricity networks and network to home), State¹² and Federal¹³ statute and regulation govern the manner in which electricity networks can be created and interfered with;
2. At the suburban level (within neighbourhoods, between homes and businesses), planning schemes¹⁴ and laws govern the manner in which properties may be developed, including in relation to the installation of electricity devices; and
3. As between private entities (individual people, corporations and others), contracts must be made or licenses issued which provide each individual with sufficient rights to access, utilise and maintain any electricity device.

Additionally:

1. Both at an infrastructure, and residential/business level, safety standards and regulations govern the installation, management and maintenance of electricity devices. And,
2. The Australian Consumer Law applies to all businesses, including electricity businesses.

These laws may impact the standards applicable to equipment for energy supply, connection to electricity supply and supply of electricity generally. Broadly speaking, Figure 15 (below) identifies how the law intersects:

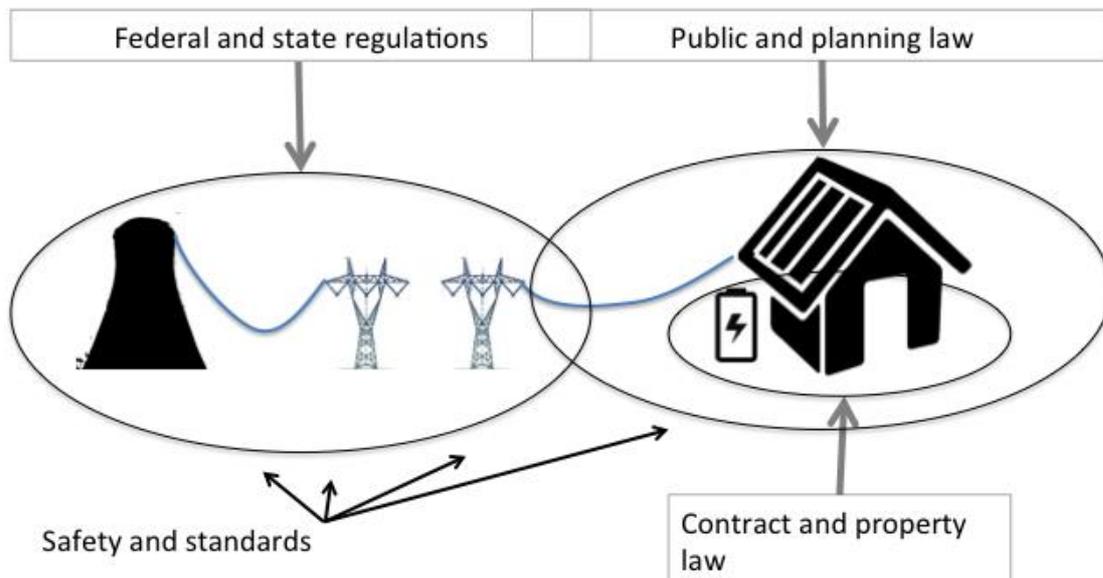


Figure 15 Representation of the applicable legal regime

Microgrid configurations include the sharing of generated energy, and may result in homeowners being connected to, or disconnected from, the public utility. Some microgrid options require that energy is shared between private titles and that an electrical easement crosses these titles “behind the meter”.

¹² *Electricity Distribution Code Version 9*, The Essential Services Commission (Vic), December 2015

¹³ Energy Industry Act 2000 (Cth), National Electricity Rules and National Electricity (Victoria) Law (contained within the schedule to the National Electricity (South Australia) Act 1996)

¹⁴ c.f. Moreland Planning Scheme 2016, Planning & Environment Act 1987 (Vic) and Planning and Environment Regulations 2015 (Vic)

A legal instrument to control various aspects of a microgrid may need to include these operational controls for:

- conflict management
- entry and exit obligations - how to sell out, how to buy in if an additional title wants to join
- how changes in demand are managed (for example, if a low demand house becomes a high demand house)
- rolling replacement of plant, and
- physical access - to allow members or service people to see or fix systems.

It is important also to consider how a shared asset can cause or in fact prevent conflict. A well-defined, up-front legal agreement will set expectations for how the system is to be operated and shared and how, if a participant is dissatisfied, they can leave the arrangement. Setting these things out and getting binding legal agreement will avert a wide range of potential conflicts. If the systems are installed and operated by a third party then conflict may be limited to a householder and the third party rather than among the microgrid participants. Again, the PPA contract and the Australian retail energy rules define quality of service, contestability and a range of consumer protections.

Since a microgrid agreement (whether a private contract or a PPA or lease) is a community agreement among people who live near each other and who are likely to know each other, then new incentives for cooperation can be inferred such as:

- joint concern and joint benefit for resolution of over-shadowing of shared PV arrays
- awareness of neighbours being at home or not since excess unused energy is disbursed back through the network
- support from neighbours if a homeowner has electrical problems or issues with their connection to the microgrid
- common concern and pride over a shared asset or activity, and/or
- natural cooperation and informal mediation by other neighbours for conflict among any two members of the microgrid.

Regulatory considerations

Australia is in the final stages of transitioning to a statutory framework of national energy laws, together with rules made by an independent national rule maker (the Australian Energy Market Commission (AEMC)). This framework is embodied in the National Electricity Law (NEL), applied as a law of Victoria under the *National Electricity (Victoria) Act 2005 (Vic)*.¹⁵

Broadly speaking, in Victoria, a complicated regime of exempting and licensing bodies

Energy generated in the National Electricity Market is sold wholesale in a spot market which services Victoria. This wholesale market is monitored by the Australian Energy Regulator, which also monitors the electricity transmission (from

¹⁵ *Victorian Licensing Arrangements – Issues Paper*, available at www.energyandresources.vic.gov.au

transmission line to customer) and distribution (generator to regional or metropolitan area) networks in Victoria.

The national electricity wholesale market is further administered by the Australian Energy Market Operator. The Australian Energy Regulator monitors wholesale energy markets for compliance with the legislation and rules which govern them.

Under the Retail Law (monitored by the Australian Energy Regulator) a person must either be an authorised retailer, or hold an exemption, in order to sell energy. The AER monitor wholesale electricity markets, limits revenue network businesses can recover, (AER) issues licenses or exemptions based on the National Energy Rules. The Essential Services Commission of Victoria issues its own licenses and exemptions for Victorians based on these national rules¹⁶. This system controls how energy utilities are established (generators and networks) and it issues retail licenses to energy retailers. In this system, generators and networks are regulated monopolies while retailers compete in a common market. Some parties provide multiple services in generation, network and retail. It is the monopoly status of distributors that affects private sharing of electricity.

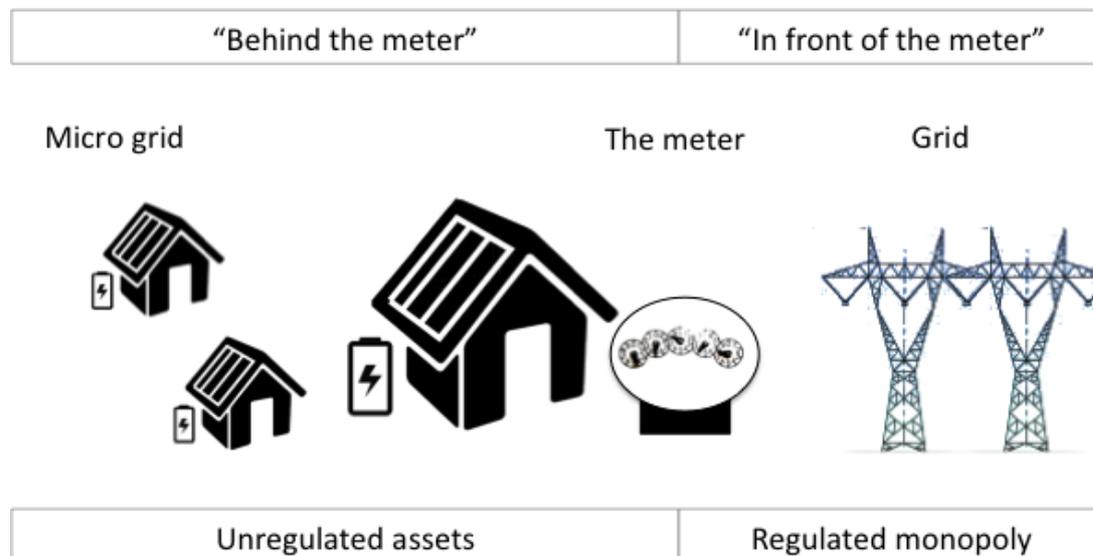


Figure 16 - Energy assets ownership and placement

The neighbourhood network is a regulated asset of the utility. The meter is a network requirement of the AER. All wiring and assets behind the meter are privately owned, unregulated assets. This would include a microgrid.

These regulations are relevant to this measure because any utility distribution system connecting to an Australian dwelling or business is granted a regulated monopoly.

The electricity supply chain between the generators and consumers is divided in the competitive generation sector, the monopoly network businesses and the competitive retail sector. The generator sector operates as a spot market with many generating companies competing to provide energy to be delivered to consumers¹⁷.

¹⁶ <https://www.aer.gov.au/system/files/Copy%20of%20GeneralOrderMay02.pdf>

¹⁷ <http://www.aemc.gov.au/About-Us/FAQs>

The Council of Australian Governments (COAG) Energy Council is currently undertaking consultation regarding the regulatory implications of stand-alone energy systems in the energy market (COAG Energy Council August 2016) and sets the policy context for consideration:

“A key policy question going forward is whether there is value in regulating stand-alone systems under a national framework and, if so, what this framework should cover. A further important policy question is whether barriers exist, be it in the national frameworks or jurisdictional instruments, which prevent stand-alone being built to replace grid-extensions where it is the most economically efficient way to serve those customers” COAG Energy Council 2016:4).

Conclusion

Demand is changing

The national electricity market's overall electricity demand has reduced 9% over the past six years to 192 TWh, due to a decline in manufacturing and increased uptake of energy efficiency and solar PV, which affects consumers' demand for grid-supplied electricity. At the same time there has been significant growth in peak summer demand, due largely to the uptake of air conditioning. A range of factors will contribute to making Australia's demand even peakier in the future such as increasingly hotter summers due to climate change, more people using electricity for heating and the power needs of rising electric vehicle use.

These trends are challenging existing business models and calling into question the viability of traditional approaches to cost-effectively provide security of supply for short intervals. In many cases it will be more financially prudent to deal with peaks in demand not by increasing generation capacity such as gas turbines and upgrading networks, but by employing demand-side solutions and more strategically deploying renewable energy generation both behind and in front of the meter.

Supply is changing

Renewable energy sources have increased to 15% of total generation in Australia in 2014. Australia's renewable uptake in recent years has been dominated by small-scale solar, principally household (or rooftop) solar PV, which now comprises 15% of renewable energy. Australia has the highest rate of rooftop solar uptake internationally, at more than one in seven households.

While the average size of solar PV systems has steadily increased in recent years, declining feed-in-tariffs and rebates mean households currently size their solar system to match their maximum daily energy demand rather than their rooftop capacity. There is hence a substantial under-utilisation of potential household rooftop solar capacity and the value of this capacity may be exploited through microgrid models where the network value of the generation is recognised in the business case for investment.

Getting the balance right

Whether through large-scale solar and wind farms or distributed rooftop solar, renewable energy sources create technical challenges for network operators to maintain a smooth and reliable electricity supply. Although certainly not an insurmountable problem, the intermittent nature of solar and wind power impacts the second-to-second balance between total electric supply and demand of traditional networks, which have very minimal capacity to store excess energy or compensate for gaps in supply.

In addition, the grid was designed to transport power from central generators to households; 'reverse power flow' from distributed solar to the grid leads to voltage regulation issues and can create potential safety risks.

There is also the risk that without appropriate network planning and control, batteries could increase rather than reduce unplanned and peak demand; for example, through households charging electric vehicles during an early evening peak, or through battery discharge patterns that contribute to, rather than ameliorate peak demand; for example, if a battery discharged fully and the household suddenly required the grid during a peak event, this could cause problems for the network if not managed/coordinated.

A microgrid can operate behind a single connection to the main grid, as shown here, with interconnected loads and generation sources enabling sharing of resources and lower net energy flows with the main grid.

Finally, network operators are concerned about the maintenance implications of the increased intensity of wire use associated with distributed generation. In locations where solar PV penetration has been high, feeding in excess solar power has been curbed, meaning the consumer receives no value for their excess generation.

Storage can help the network

By storing excess energy and discharging it into the grid at a 'steadier' rate and at peak demand periods, batteries can assist network operators to manage technical issues associated with intermittency, voltage rise, voltage variability and peak demand, including unscheduled peak events. Batteries can also potentially provide power in the event of a network outage.

Sharing can help balance

Sharing solar PV generation and battery storage across a number of households has the potential to leverage the opportunities and help manage some of the risks inherent in the changing electricity sector.

It can help sidestep network limits on distributed energy resources and enable residential customers to generate, store and use more of their own solar PV. The ability to locally store and deploy energy to match variable local demand, say among a group of households with different load profiles, can be served by solar and batteries configured in a microgrid or virtual power plant.

Moreover, aggregated storage capacity has the ability to reduce peak demand, thus actively assisting network utilities to manage challenging periods of variable power production and overall activity on the grid.

Microgrids can also provide other benefits, such as reducing the total capital costs for households and utilities. An example is where a new residential development uses on-site generation and storage to reduce consumption and guarantee a maximum peak demand. This in turn can reduce both the sizing of distribution

infrastructure (the poles and wires) and the costs associated with connecting to the broader network.

Financial viability

To be viable, in front of the meter projects need to reflect the benefit to the network operator, not just the consumers. The value for all shared energy models is a balance of system costs (for capital and ongoing operations) and benefits from reduced costs for energy delivery and network infrastructure. Costs and benefits vary from project to project, with the magnitude of network benefits in particular being highly sensitive to the state of the local network.

Projects such as microgrids may introduce significant infrastructure costs and associated operations and maintenance costs. They may also incur admin costs to manage customers, provide billing and coordinate maintenance.

Projects need a competitive offering (i.e. better than an alternative), willing customers and the ability to operate effectively over time. Just like going off-grid can be more expensive than remaining connected in an urban area, a microgrid may not bring benefit if its capital and operating costs outweigh the savings, or if it can't attract customers.

So where does in front of the meter work best? Recent concepts such as local energy trading (or virtual net metering) have sought to match energy surplus and energy demand between two sites. While the benefit to each end user has been identified, in many cases projects are frustrated by the cost and regulations associated with transporting the energy across the grid.

New in front of the meter models are recognising two key paths, where the grid is avoided or where the grid is supported, that recognise the impact that capital infrastructure cost has in determining viability.

The grid

In areas of network constraint or where power supply quality is poor, microgrids and virtual power plants can provide network support by reducing total load on the network, or providing local generation or power quality services. In these situations, a project can benefit from reduced connection fees or service payments.

In some situations, the cost of extending or maintaining the grid may be avoided by establishing a microgrid. Areas at the edge of the grid such as new residential developments or remote communities are key examples. For residential developments where there is no infrastructure, it can be cost effective to invest in distributed energy resources and control systems to allow the development to dramatically reduce or remove its reliance on the broader grid. This can reduce the connection costs for the developer and reduce operating costs for residents. For some regional or remote communities, microgrids can be an alternative to maintaining an expensive network connection.

To meet the challenge of 100% renewable electricity supply, we will need to better coordinate supply and demand variability across the grid. Where there have been barriers in the past, new partnerships that link supply and demand benefits are emerging. These in front of the meter initiatives may well stem a grid defection trend and be a significant enabler of a decarbonised grid.