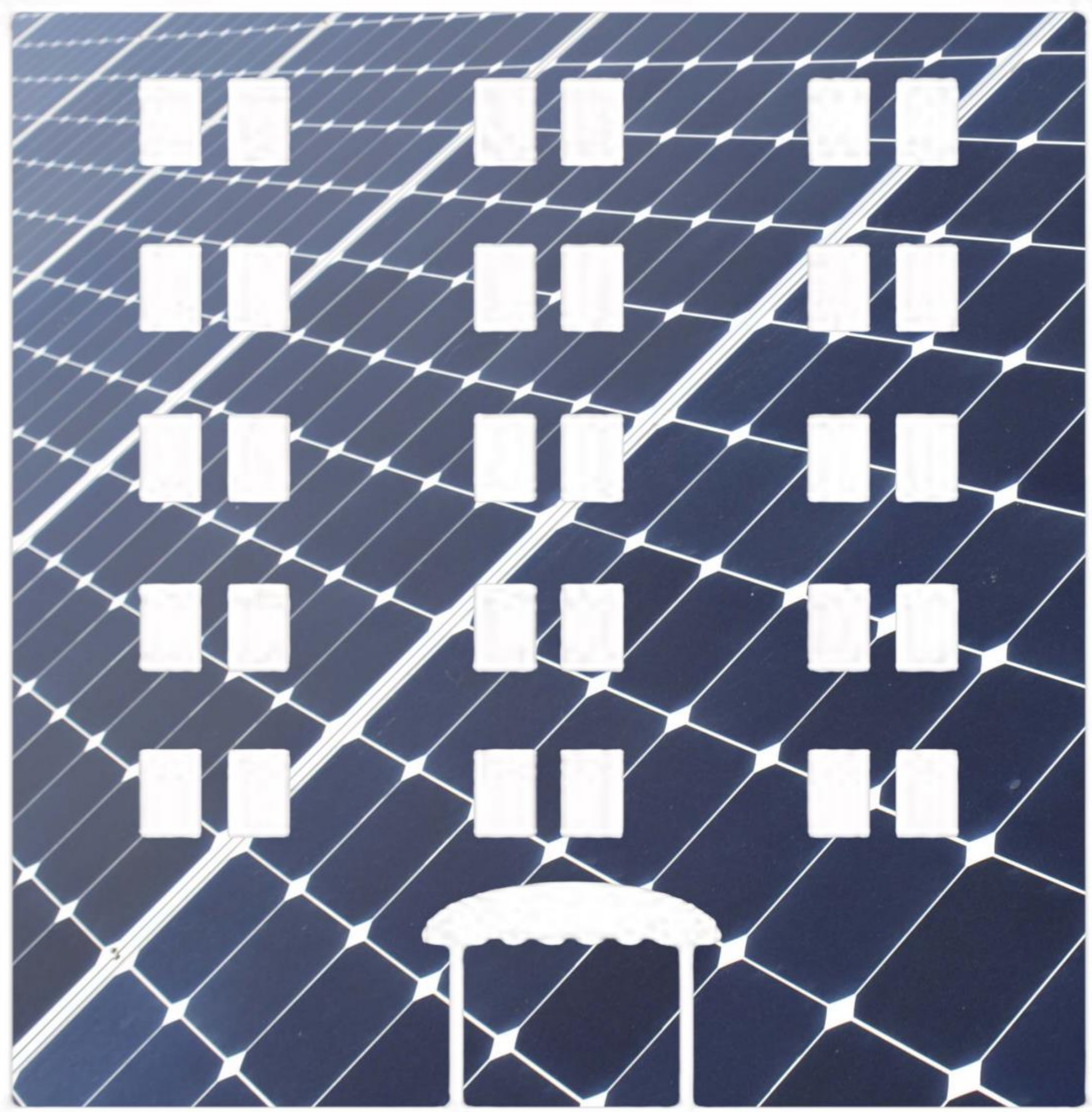
Photovoltaics on Apartment Buildings



Project Report

Centre for Energy and Environmental Markets (CEEM)
UNSW Sydney

Energy Consumers Australia
ECA Research Project AP841

Executive Summary

The Opportunity

Australia has over 2 million solar households (22% of houses) but apartment dwellers are largely excluded from the benefits of clean, cheap solar generation.

- There are 1.4 million apartments in Australia, housing 10% of the population nationally but two thirds of residents in some urban LGAs, while one in three of all new dwellings are apartments.
- There is potential for an estimated 2.9-4.0 GW of solar PV on the roofs of Australian apartment buildings, equivalent to approximately half the existing installed residential capacity. On average 1-2 storey buildings have capacity for 3.7kW per apartment, 3 storey have 2.0kW/apartment and higher buildings average 16kW/apartment. Over 60% of apartments are in 1,2 or 3 storey buildings.
- On average, apartments use 79% of the electricity per occupant of detached and semi-detached houses. Apartment loads show greater temporal variability, and more diverse peak times than houses, resulting in greater benefits from aggregating diverse loads.
- Apartment building common property loads are highly building specific. Daily demand varies from 2 to 15 kWh/day/apartment, while load profiles often have higher daytime load and are flatter than household loads.

The Challenges

Despite a range of potential benefits over stand-alone housing, including potential economies of scale, aggregation of diverse household loads, and established governance arrangements for shared ownership, there are multiple challenges to deployment of solar PV on apartment buildings.

- Many apartment buildings have physical constraints on solar installation, including rooftop obstructions, competition for roof space, overshadowing, outdated wiring installations and structural issues, as well as access requirements that can significantly increase installation costs.
- Split incentives, high turnover of residents and owners, poor communication and other organisational issues can present barriers to co-ordinated action.
- Apartments are excluded from many solar incentive schemes and strata bodies may have difficulty in accessing finance for investment in solar.
- Strata Laws can present barriers to sustainability upgrades while electricity market regulation can make it difficult for electricity consumers to co-ordinate their energy supply arrangements.
- Lack of objective information for residents and shortage of solar installers with strata experience make decision making difficult.

Implementation Arrangements

Optimum arrangements for installing solar PV depends on the specific characteristics of buildings, households, electricity loads and financial arrangements; there is no "one size fits all" solution.

- For buildings with significant common property (CP), PV systems installed by the strata body to meet CP loads are less administratively and organisationally complex than other arrangements and have payback periods comparable to those for residential houses. For buildings with relatively small roof areas (e.g. high-rise), this is often the optimum arrangement.

- PV installations for individual apartments face governance challenges and low self-consumption but can be simpler to implement than shared systems and can be financially optimal, particularly for smaller buildings.
- Embedded networks have not always been beneficial for customers, and retrofitting to some buildings can be expensive, but if they are owned and operated in the interests of residents and owners, they can result in significant cost savings.
- A shared PV system applied to aggregated building load can significantly increase PV self-consumption and building self-sufficiency compared to individual systems. PV added to an embedded network can reduce costs for consumers.
- Shared PV purchased behind-the-meter through a solar PPA can also provide significant benefits, while avoiding the regulatory challenges and upfront costs of an embedded network.
- Shared battery storage can further increase PV self-consumption and reduce demand charges but is unlikely to be financially beneficially without a substantial decrease in capital costs.
- Off-site solar avoids many of the challenges and may be the best opportunity for some residents to access solar generation, but financial benefits are restricted by high network costs.

Policy Recommendations

Regulatory reforms in areas of Strata, Electricity and taxation Law, as well as targeted financial incentives, could help apartment owners to access the benefits of solar energy.

- Changes to Strata decision-making processes and specific exemptions for sustainable infrastructure.
- Allowing strata bodies to use common property as collateral for loans.
- Inclusion of apartment tenants in strata decision making.
- Reversal of tax incentives for property investment.
- Targeted government incentives for PV feasibility studies and installation in apartment buildings
- Allowable retail and embedded network exemptions for EN operators owned by or constituted to benefit residential electricity consumers.
- Restrictions on developers' ability to enter into long-term energy supply contracts.
- Removal of unnecessary metering criteria and simplification of meter transfer arrangements.
- Introduction of cost-reflective pricing for use of local distribution networks.

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While many people have contributed to the project, the analysis and conclusions in the report are the responsibility of the authors alone.

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Please note that some passages in this report have been reproduced verbatim from [1]. A full list of the publications associated with research and analysis covered, at least in part, by this report can be found in Appendix A.

Disclaimer

The authors have used all due care and skill to ensure the material is accurate. However, CEEM, UNSW Sydney, ECA and the authors do not accept any responsibility for any losses that may arise by anyone relying upon its contents. In particular, the financial costs and benefits of PV installation are highly dependent on building and household characteristics as well as on financial arrangements with retailers and other stakeholders.

List of abbreviations

BESS	Battery energy storage system
BTM	Behind the meter
CEEM	Centre for Energy and Environmental Markets
CP	Common property
CRE	Community renewable energy
DNSP	Distribution Network Service Provider
PV	Photovoltaic
ECA	Energy Consumers Australia
EN	Embedded network
ENM	Embedded network manager
ENO	Embedded network operator
FiT	Feed-in tariff
LGA	Local Government Area
PPA	Power purchase agreement
TOU	Time of use

Contents

1. Introduction

1.1 Context

More than one in five Australian households (22%, a world-leading proportion) have installed solar photovoltaic (PV) panels [2] on their roofs and are enjoying the benefits of cheaper, cleaner electricity. Initially, this deployment was driven by high, state-subsidised Feed-in Tariffs (FiTs) which have now been largely discontinued, but dramatic reductions in the cost of PV systems, along with increasing electricity costs, have maintained a buoyant market in residential PV, with householders motivated by bill reduction, hedging against future electricity price rises, a greater measure of self-sufficiency from electricity retailers, as well as by environmental concerns [3].

Meanwhile, along with renters, the 10% of Australians who live in apartments have been almost entirely excluded from this residential solar revolution. The uneven distribution of apartments (Figure 1) means that in some Local Government Areas (LGAs), over 70% of the population are ‘locked out’ of access to solar energy.

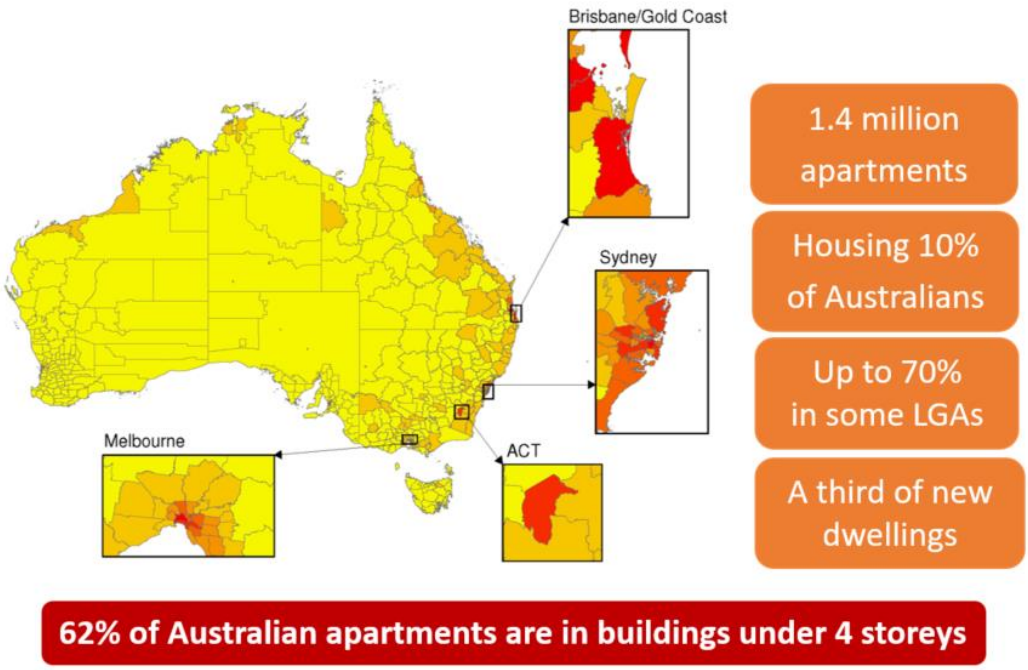


Figure 1 Apartments in Australia by LGA

Unlike owners of detached, semi-detached, and terraced houses and townhouses, very few apartment residents have PV installed on their buildings. Although apartment residents are as diverse as the building stock itself, young, single people, overseas-born Australians and households with a low gross income are disproportionately represented [4, 5]. These include people least able to deal with escalating energy bills and arguably most in need of future price certainty.

The reasons apartments lag behind the rest of the residential sector for PV deployment are many and varied [6]. They include physical limitations of the apartment building stock, demographic factors and knowledge issues. However, a number of regulatory factors, including governance of apartment buildings and regulation of the energy market, also act to restrict the options available to apartment residents. As with many aspects of apartment living, installing solar PV requires a degree of co-operation between owners and residents that is vulnerable to communication barriers and split incentives. A co-operative approach is not well facilitated by energy regulations which assumes consumers act individually and independently in their engagement with the electricity market. Moreover, apartment residents are subject to a “fourth tier” of governance in the form of Strata Law, and this is a significant factor in denying them the same access to renewable energy opportunities enjoyed by house owners.

Given these challenges, it could be suggested that it would be more effective to focus on the lower-hanging fruit of incentivising PV installation on the remaining 78% of houses. However, as well as helping to address the equity issues discussed above, increasing deployment of PV on apartment buildings has potential societal benefits, including reducing carbon emissions and assisting Australia to meet its commitment to the Paris Agreement. Moreover, as they are predominantly situated in urban areas, apartment buildings are more likely than houses to be located close to commercial daytime loads, where increased on-site generation may reduce the need for augmentation of the electricity distribution network and consequently reduce costs for all electricity consumers.

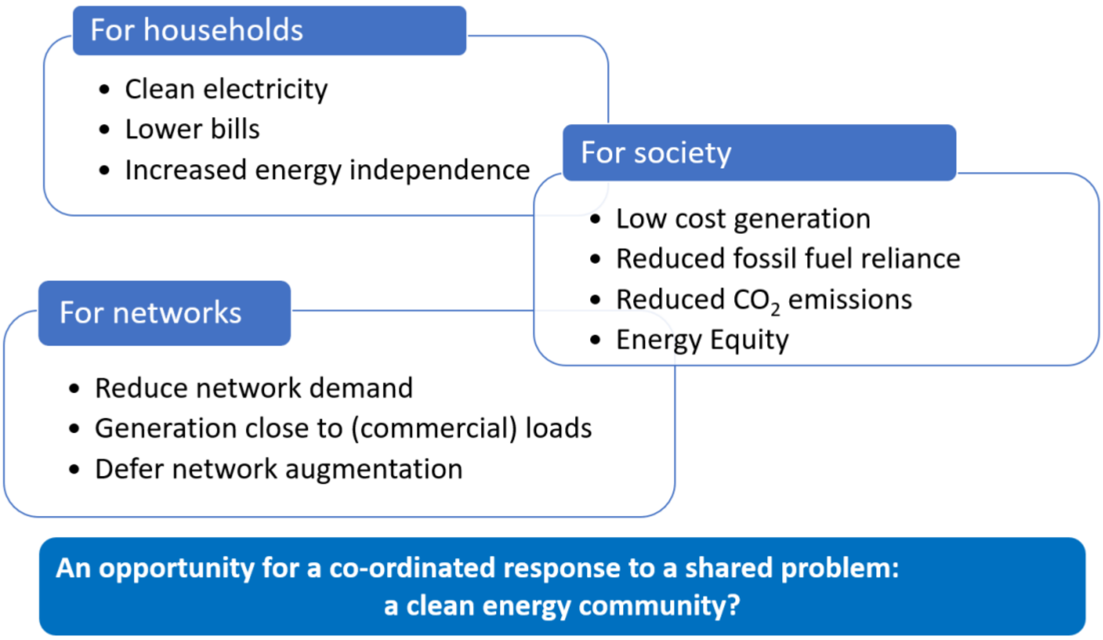


Figure 2 Potential benefits of increasing apartment PV deployment

Apartment buildings also have a number of characteristics that might make them *more* suited to PV deployment than houses: commonly owned roofs with the space to install larger PV systems than individual houses and so benefit from economies of scale; potential for aggregation of diverse, physically proximate household electricity loads with possible benefits of flatter load profiles and increased self-consumption of PV generation; and established structures for community organisation, collective ownership, decision-making, and management of expenditure.

If deployment of PV on apartment buildings has a place in a future distributed energy system, Australia, with its high solar resource, mature distributed PV industry and world-leading residential PV penetration, might be a likely location. Yet the country has almost no apartment PV.

There is a need for a greater understanding of the scale and nature of the opportunity for deploying PV on apartment buildings and the technical and business models available for implementation. Clear information about the costs and benefits of different approaches can help decision making for apartment residents and inform policy approaches for incentivising greater PV deployment on apartment buildings.

1.2 Project aims, objectives and methods

This report is the result of a two-year exploration of the opportunities for PV on Australian apartment buildings. The stated aim of the project is

to improve investment decision making in relation to deployment of PV on Australian apartment buildings, thereby enabling apartment residents to potentially share the financial and other benefits of on-site renewable energy deployment, as well as increasing competition in the retail energy market, and improving the efficiency of network investment over the long term.

This has been approached through generating a strong evidence base outlining the scale of the opportunity, the potential consumer benefit and, critically, the regulatory, financial and organisational arrangements that could help facilitate deployment.

The project used multiple methodologies to develop this evidence base:

1. A series of **semi-structured interviews** of a diverse group of stakeholders including apartment residents (predominantly owners), Executive Committee members, consultant engineers, embedded network operators, community energy advocates, academics, local government officers, strata / building managers and strata resident advocates
2. Collection and **analysis of apartment building load data**. The existing Smart Grid Smart City [7] dataset, containing annual half-hourly electricity load data for 6000 households, was analysed to better understand the particular characteristics of electricity use in apartment households. Common Property load data for ten diverse Sydney buildings was also analysed. Additionally, meters were installed in NSW apartment buildings to record highly granular load data for apartments, common property and whole building over the course of a year.
3. A **techno-economic too**l was created to **model, electricity flows and financial outcomes** in apartment buildings with rooftop PV and battery storage. This was used to model a range of technical implementations including individual PV systems for common property and / or apartments, shared behind-the-meter arrangements and embedded networks. The Python code for the tool has been made open-source[1] and is being further developed with an accessible Graphical User Interface to enable it to be used by non-specialists.
4. A detailed **review of the legislative environment** affecting PV deployment on apartment buildings was carried out, including jurisdictional strata law and regulations relating to electricity retailing and embedded networks. A number

[1] The Python tool can be downloaded from https://github.com/mike-b-roberts/morePVs and the accessible version with user-friendly GUI will be available on the CEEM website (http://ceem.unsw.edu.au/open-source-tools) in 2019.

of submissions were made to the regulatory processes of the Australian Electricity Market Commission (AEMC).

5. An **assessment of the rooftop solar potential** of Australian apartment buildings, combining GIS analysis techniques with building census data, was carried out to better understand the scale and nature of the opportunity.

The findings of the project are summarised below. Section 2 presents the technical opportunity, in terms of solar potential of apartment building roofs and the suitability of apartment building loads to PV deployment. Section 3 describes the barriers faced by apartment residents in installing rooftop PV. Section 4 introduces the possible technical arrangements for deploying PV on apartment buildings, identifies the advantages and disadvantages of each and analyses their costs and benefits. The implications for strata body decision makers are outlined in Section 5 and in Section 6 we suggest some policy approaches that could help increase PV deployment in this sector.

2. The opportunity

2.1 Solar potential of apartment rooftops

There are in excess of 1.4 million apartments in Australia, housing 10% of the population [8] while a third of all new residential dwellings given building approval are apartments [9]. However, these headline statistics obscure the uneven distribution of apartment buildings across the country and that apartment residents are in the majority in some urban Local Government Areas (LGAs) (see Table 1).

Table 1 LGAs with highest % of apartment dwellers

LGA	% population in apartments
North Sydney	66.8%
Melbourne	62.2%
Perth	61.6%
Sydney	59.2%
Port Phillip	56.6%
Waverley	53.4%
Strathfield	46.2%
Woollahra	45.8%
Botany Bay	45.8%
Randwick	45.1%
Canada Bay	44.7%
Lane Cove	41.1%
Stonnington	40.9%
Mosman	40.4%
Yarra	39.1%
Burwood	38.2%
Willoughby	37.8%
Rockdale	36.8%
Inner West	33.0%
Parramatta	32.8%

Australian apartment buildings are is diverse in height and structure, with consequent variability in their rooftop solar potential. High-rise apartment buildings have very low rooftop generating potential compared to the building loads (but can still benefit from installing PV on the available area). However, 61% of apartments are in buildings of three storeys or less, with potential PV capacity to make a significant contribution to the building load.

Our analysis of the solar potential of apartment building roofs in the City of Melbourne [10] found that, on average, apartment buildings have a greater proportion of total roof area suitable for PV installation than houses but, more importantly, that the average potential PV capacity on three-storey apartment buildings is 3.2kW per dwelling, slightly more than half the average potential on stand-alone houses in the LGA, and that buildings with four or more storeys have an average potential PV capacity of 1.6kW per apartment (see Table 2). Note that these are average figures and that, as with houses, solar potential is highly variable (as shown by the high standard deviation in Table 2) and dependent on specific building characteristics as well as shading. Nevertheless, this suggests that many apartment buildings have sufficient PV capacity to make a significant contribution to household loads.

Table 2. Mean usable area and PV potential per dwelling in City of Melbourne by dwelling type

Dwelling Type	**Mean usable area per dwelling**	**Mean PV per dwelling**	**Standard deviation of PV per dwelling**
House	40.3 m^2	6.0kW	3.8 kW
Townhouse	35.5 m^2	5.4 kW	3.3 kW
1 or 2 storey apartment	34.9 m^2	5.3 kW	3.7 kW
3 storey apartment	20.8 m^2	3.2 kW	2.0 kW
4 or more storey apartment	10.3 m^2	1.6 kW	1.4 kW

The same study estimated that there is sufficient roof area on Australia's apartment buildings to install a total of between 2.9GW and 4.0GW of PV, nearly half of which is in NSW (see Figure 3).

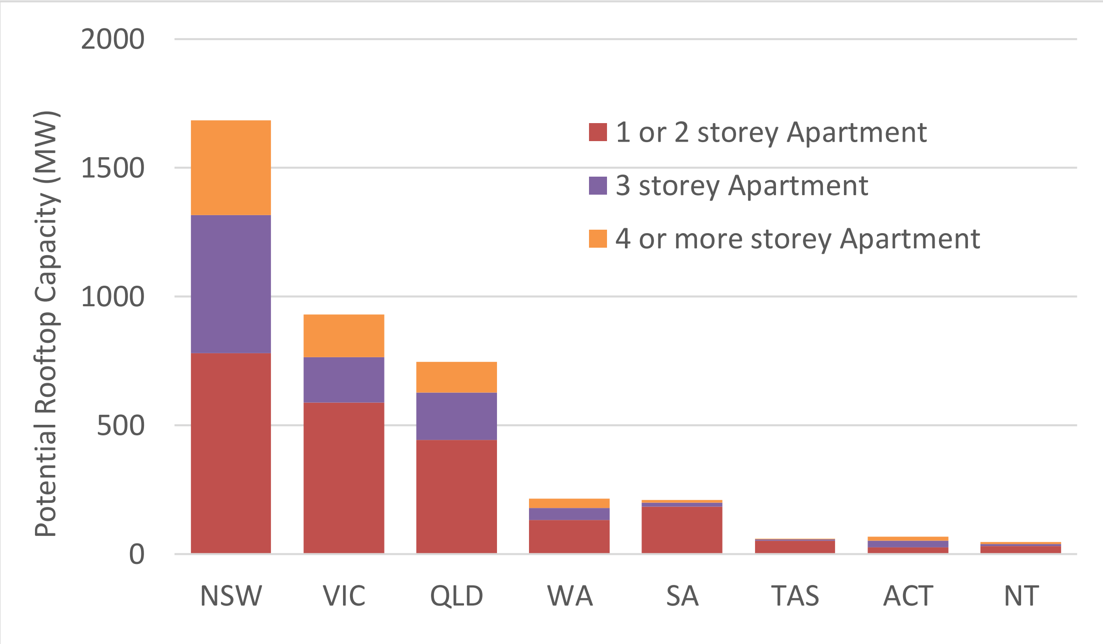


Figure 3 Estimated potential PV capacity on apartment roofs

Although this potential is small compared to the unutilised potential on houses (estimated by the same study to be 43GW – 61GW) or to the potential capacity on commercial buildings which often have proximate daytime loads, it is certainly significant – about half the total amount of rooftop PV currently installed in Australia (8.1GW).

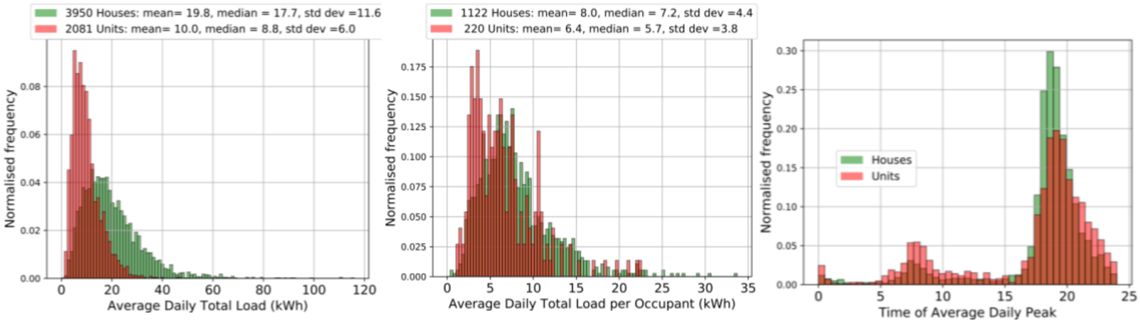
2.2 Electricity loads in apartment buildings

One of the challenges to understanding the opportunity for deploying PV on apartment buildings is a lack of published data about apartment building electricity loads. This project included detailed analysis of these loads [11], using annual load profiles with 30-minute interval data from a published dataset of 6000 NSW households [7], including 2000 apartments, and common property loads from 25

Sydney buildings. The findings are summarised below.

i) Apartment loads

It would be expected that apartments use less electricity than houses, and the study found that the median daily load for apartment households to be half that for detached and semi-detached houses (8.8 kWh/day compared to 17.7 kW/day) [11], which is only partially explained by the lower average occupancy rates of apartments (1.9 compared to 2.7 for houses) [12]. The daily energy use *per* occupant is also 21% lower for apartments at 5.7kWh/day compared to 7.2kWh, though it is unclear whether this is due to the smaller floor area per occupant reducing heating and cooling loads, the lower proportion of outside walls (and floors / ceilings) reducing thermal losses and gains, lower ownership of air-conditioning, or other factors.



(a) *(b)* *(c)*

Figure 4 Frequency distribution of (a) average daily total load, (b) average daily load normalised for occupant and (c) average time of daily peak [11]

Like other households, electricity use in apartments typically has a small morning peak and a higher evening peak. However, the study also found that apartment load profiles typically show more variation through the day, and lower load factor (ratio of average load to peak load). Greater diversity of peak time and of daily variability was observed between apartments than between houses. One consequence of this greater diversity is that the 'flattening' effect of aggregating loads from multiple households is more pronounced for apartments than for houses. This results in potential customer benefits when peak demand or capacity charges are applied to aggregated building loads, as is typical for embedded networks.

ii) Common property loads

The Australian apartment building stock is highly diverse in terms of height, age, construction and facilities. Consequently, the electricity loads associated with common property (CP) vary considerably between buildings. These loads can include lighting for common areas, stairwells and carparks; lifts; water heating and pumping for centralised hot water and/or for pools; heating, ventilation and air conditioning (HVAC) for common areas and sometimes centralised HVAC for all units, as well as additional facilities such as centralised laundry, gym, sauna, etc. Although CP energy use can be relatively small in low-rise walk-up apartment buildings, it can account for over half of the total building energy usage in some high and medium rise buildings where vertical transportation and communal service area requirements increase markedly. A study of CP load data for 25 Sydney apartment buildings [13] found average daily CP loads between 2.0 and 15.1 kWh/day/apartment.

Similar to other residential loads, common property loads typically have morning and evening peaks, but some buildings have continuous loads that result in load profiles that are flatter (and more suited to PV deployment) than apartment loads (Figure 5).

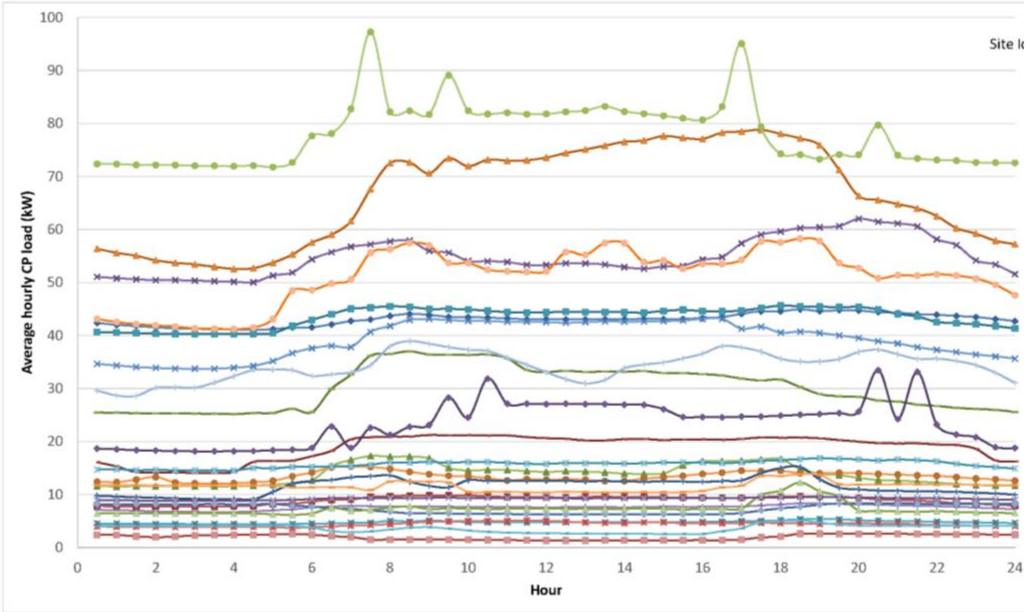


Figure 5 Average weekday CP load profiles (kW) for 25 NSW buildings [2]

In many buildings, there is considerable scope for energy efficiency (EE) improvements to the common property to reduce and/or shift demand through installation of efficient devices (LED lighting, low torque lift motors, efficient extraction fans) and to improve demand management through motion sensors, carbon monoxide sensors and time switches, with some buildings reporting bill savings up to 40%.

It would be useful to extend this research to gain a greater understanding of the relationship between apartment load profile and climate zone as well as a wider range of building and household characteristics (including floor area, appliance ownership, building structure, resident demographics and lifestyle).

[2] Data courtesy of Energy Smart Strata

3. Apartment PV – advantages and challenges

Apartment buildings have a number of characteristics that might give them an advantage over stand-alone houses in deploying rooftop PV.

- Their commonly-owned roofs often have the space to install larger PV systems than individual houses, enabling them to benefit from economies of scale and so reduce capital costs.
- There is potential for aggregation of diverse, physically proximate household loads with possible benefits of flatter load profiles and increased self-consumption of PV generation, as well as for co-ordinated engagement in the retail electricity market to access lower commercial tariffs.
- Strata bodies represent established structures for community organisation, decision-making, and management of expenditure.

Despite these advantages, and Australia's high solar resource, mature distributed PV industry and world-leading residential PV penetration, the country has almost no apartment PV. This is due to a wide range of factors [6] which disadvantage apartment residents compared to house dwellers. These are summarised below.

3.1 Physical limitations of building stock

The diverse apartment building stock can create multiple challenges:

- Insufficient roof-space (particularly high-rise)
- Alternate use of roof space (common areas, gardens, pools, etc.)
- Roof access issues, increasing installation costs
- Overshadowing from nearby buildings
- Rooftop fixtures causing shading or reducing space (e.g. solar hot water, air conditioning units, aerials, phone masts, housings for lift motors and safety harness fixing points)
- Fixings causing damage to waterproof membranes
- Internal cabling compromising fire separation
- Old switchboards or internal wiring need upgrading to meet standards

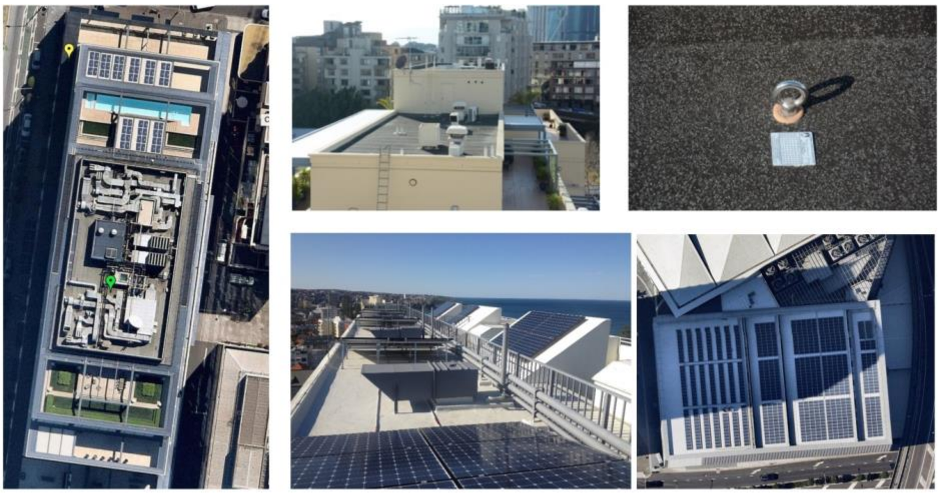


Figure 6 Rooftop obstructions and shading (clockwise from left): Roof gardens and pools, air-con, safety harness fixing points, shading, air-con.

3.2 Governance issues

Strata law means that apartment owners are subject to an additional layer of government (the “fourth tier”) compared to other homeowners which, combined with other organisational challenges of collective ownership, can restrict their access to solar energy, as well as to other sustainability improvements. Because apartment owners do not own their own roof, they are not able to act independently to install PV without agreement from the strata body.

- The requirement for a by-law to allow use of roof space can prevent apartment owners installing individual PV systems.
- Poor communication and lack of engagement within strata bodies can create obstacles to decision making, particularly where large majorities are required to authorise expenditure.
- Split incentives between owners (likely responsible for investment in PV) and tenants (likely to benefit from reduced bills) and between different types of household (with uneven benefit from cheap daytime electricity) can impact decision making.
- Split incentives between developers and apartment owners can result in the establishment of strata bodies and electricity supply arrangements that are not beneficial to owners or residents.
- The high proportion of investor-owners may result in aversion to expenditure beyond essential maintenance.
- High turnover of residents and owners can result in ‘short-termism’ requiring short payback periods on investment.

3.3 Financial issues

Access to finance to invest in apartment PV can be problematic for a number of reasons:

- Apartment residents are excluded from many of the state government schemes providing grants or low-cost loans for householders to install PV.
- Because strata bodies cannot use common property as collateral against loans, borrowing for infrastructure upgrades (including PV) is unsecured and so likely to be higher cost than for house owners.
- Use of a special levy to fund PV deployment can create inequity, while sinking funds are sometimes inadequate and are often reserved for essential maintenance.
- The lower tariffs paid by strata bodies for large common property loads or aggregated building loads can reduce the financial savings and increase the payback period for PV.

3.4 Regulatory issues

Apartment living requires a degree of co-ordination and co-operation that is sometimes at odds with the underlying assumptions of legislative arrangements. In particular, the assumption underlying regulation of the National Energy Market, that consumers are always best served by engaging individually in a competitive retail market, may act against apartment residents acting collectively to co-ordinate their engagement in the market and their deployment of rooftop PV. This is evident in the administrative barriers to installing embedded networks.

3.5 Information

There is a lack of accessible information about the options available to apartment residents for installing PV and their relative costs and benefits. Solar installers without experience of apartment buildings are sometimes averse to working with strata bodies and may provide conflicting advice.

4. Technical implementation arrangements

Most residential PV is installed on the roof of a single house and used to supply the electricity load for the household. For apartment buildings, a range of implementation arrangements are possible, with residents and strata bodies needing to choose the most appropriate for their particular circumstances. These alternative arrangements are described below.

The project included extensive techno-economic modelling of energy and financial flows in apartment buildings in order to compare the costs and benefits of these different implementation arrangements [14]. Broad findings are presented below while detailed analysis for some case study buildings is found in Appendix B.

4.1 PV for common property only

The simplest implementation of apartment PV is for the strata body to buy and install a single PV system to meet common property demand (Figure 7). In the most common business model, the strata body pays the capital costs of PV installation on the commonly-owned roof, and the benefits (in the form of reduced CP electricity bills) flow back to the strata body and can be passed on to apartment owners as reduced strata fees.

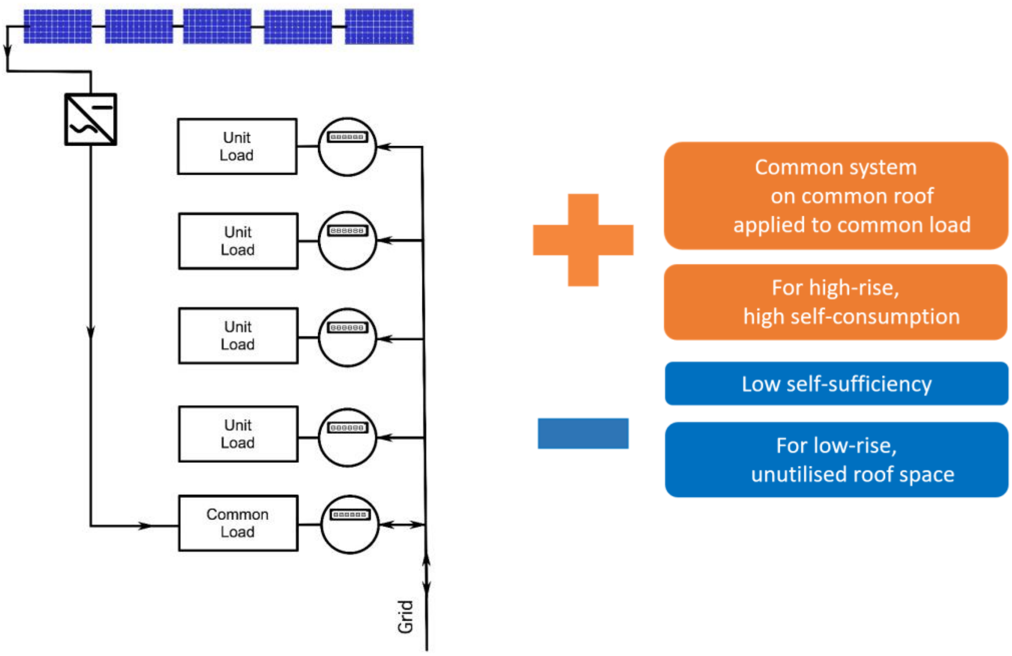


Figure 7 PV for common property load

Where CP loads are significant and roof-space is limited, as in most high-rise apartment buildings, this arrangement is likely to fully utilise the rooftop solar potential, achieve high levels of self-consumption and maximise the financial benefits to owners.

Installation is likely to benefit from economies of scale, compared to typically smaller residential systems, but may attract additional costs including issues relating to limitations of the building (section 3). Where larger CP loads attract commercial retail tariffs, the financial savings from offsetting CP load will be less than for smaller loads with residential tariffs. Typical payback periods are variable and building-dependent, but of a similar order (three to eight years for the sites modelled) to those achieved by house owners for systems sized to maximise self-consumption, while larger installations can deliver savings over the lifetime of the system if a Feed-in Tariff (FiT) is available for exported generation.

There are several potential sources of finance for strata bodies to meet the capital costs of PV installation:

- use of the Sinking Fund - often the most equitable solution, although may have to compete for funds with planned and emergency maintenance needs;
- a special levy on strata members – requires strata approval which may be difficult to obtain;
- a bank loan, likely to be unsecured and therefore at higher interest rates than homeowner borrowing (as strata law prohibits strata bodies from using the buildings as loan collateral);
- grants and subsidies from local, state or federal government.

Where strata bodies face difficulties gaining membership approval or accessing finance, alternative business models are possible where a third party pays for PV installation and either leases it to the strata body or sells the generated PV through a power purchase agreement (PPA). This could be a commercial entity or a community renewable energy (CRE) organisation. In the latter case, capital could be raised through a share offer available to residents and owners, helping to overcome the split-incentive issue.

4.2 PV for individual apartments

The installation model used by most of Australia's two million solar households is for an owner-occupier to purchase and install a PV system 'behind the meter' to supply their own residential load. This model is also possible for apartment buildings, either for individual apartments or with separate systems installed for each apartment in a building (Figure 8).

For the small proportion of top-floor apartments where the roof is owned by the apartment owner, this arrangement is as straightforward as for house owners but, for most strata-owned apartments, this involves installing individually-owned PV systems on roof area collectively owned by the strata body.

In most jurisdictions, a bylaw must be passed at an AGM or special meeting of the strata body[3]. An apartment owner wishing to retrofit PV to their building to meet their own household load therefore has to persuade a significant proportion of other apartment owners to allow use of the roof. This can act as a significant barrier to PV deployment on brownfield sites.

For greenfield sites, the by-law can be included in the initial strata title, and equity can be addressed by allocating an equal share of the suitable roof area to each apartment. Some new developments have implemented this arrangement, either installing individual PV systems for each apartment or simply allocating space for PV modules and inverters with pre-installed conduit for cable runs, to simplify the process for any owner choosing to install PV.

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[3] Requirements vary between jurisdictions, e.g., in NSW, not more than 25% of votes against the bylaw; in VIC, 75% of votes in favour [6].

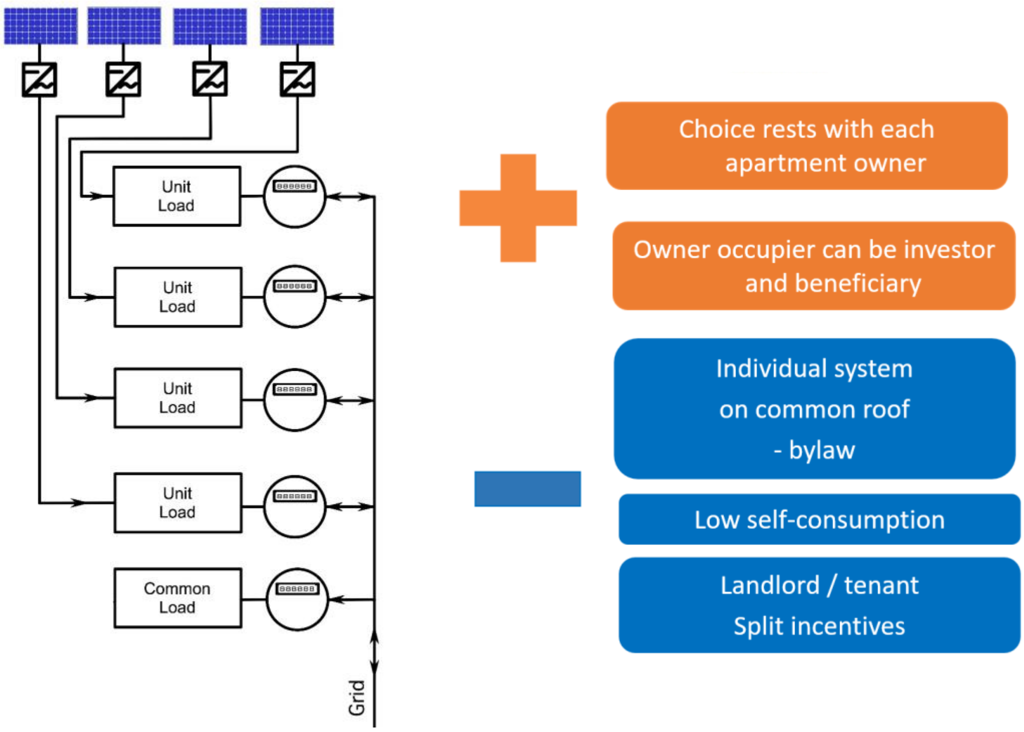


Figure 8 Individual PV for apartments

Where the governance issues can be overcome, the financial benefits of individual PV for apartment residents is dependent on matching the system size to the characteristics of the household load, and on the retail tariffs (and feed-in-tariffs) available, but payback periods similar to those for systems on houses (4-7 years) can be expected [15].

Although self-consumption is likely to be lower than arrangements with shared PV systems, this arrangement may be the most financially advantageous for some smaller apartment buildings as it avoids the capital outlay on additional distribution infrastructure.

For the 60% of apartments that are rented [12], the split incentive between owner and tenant is an additional barrier as landlords are unlikely to invest in solar if the benefit of reduced electricity bills flow to the tenant. Although startups such as SunTenants [16] and SunYield [17] are addressing this issue for rented houses, their solutions are not currently being used for apartments.

4.3 Benefits of shared PV

Because tariffs paid for imported electricity are typically much greater than Feed-in-tariffs paid for exports, it is beneficial to maximise self-consumption of PV generation rather than export it to the grid. Where apartments have individual PV systems, there are likely to be times when excess PV generation is exported to the grid at the same time as electricity is being imported to meet the building load. Figure 9 shows how a shared PV system can avoid this as on-site generation is applied first to the aggregated building load, thus increasing self-consumption.

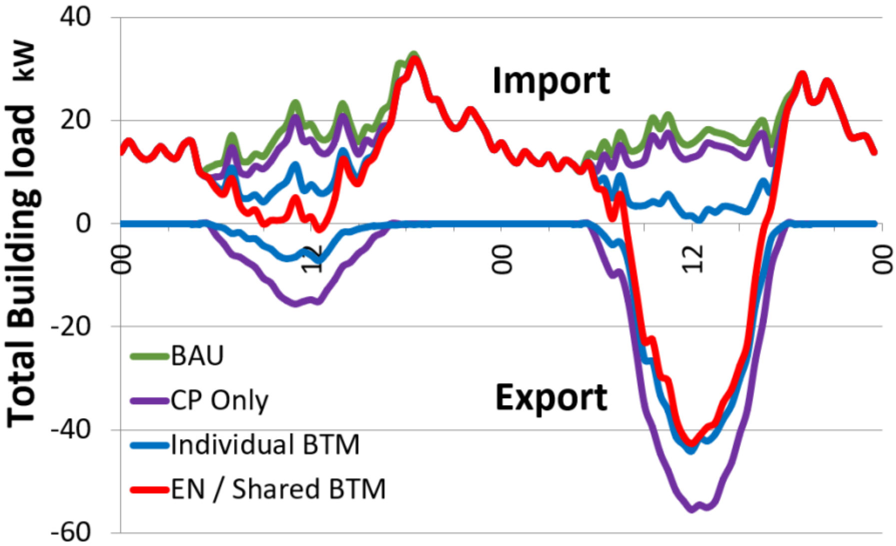


Figure 9 Total apartment building import and export over two days for business as usual (BAU), PV for common property (CP) only, individual PV behind-the-meter (BTM), or PV shared through embedded network (EN) or BTM

Figure 10 shows how self-consumption and energy self-sufficiency are increased by using shared PV systems compared to individual systems for a range of buildings with different sized PV systems.

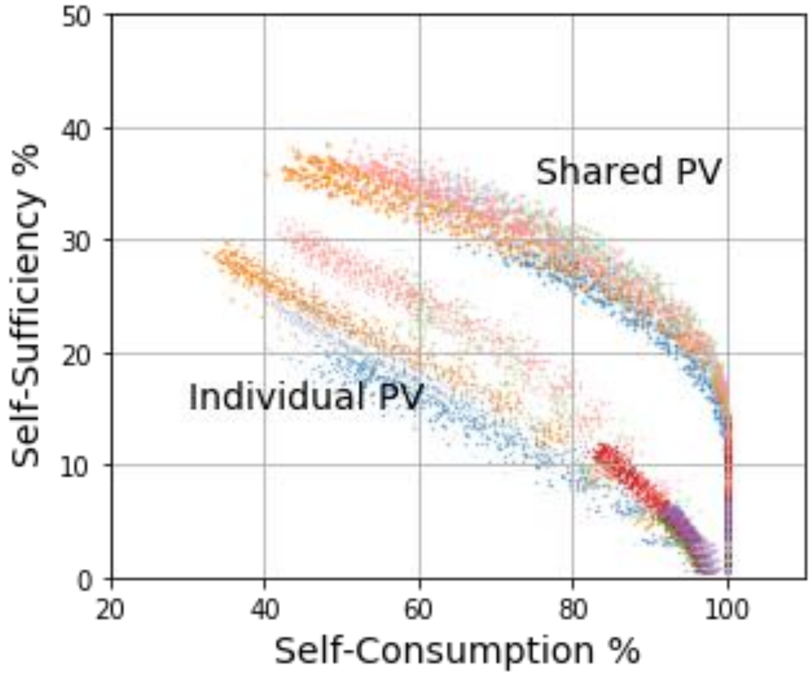


Figure 10 Energy self-sufficiency and PV self-consumption for shared and individual PV [14]

4.4 Shared PV with embedded network

One way to distribute generation from a shared PV system is to use an embedded network (EN). The embedded network operator (ENO) purchases electricity from a retailer, via the single grid connection at the 'parent' or 'gate' meter, and sells it on to residents through a ‘child’ meter for each apartment (Figure 11). If a shared PV system is connected between the parent and child meters, the on-site generation can also be sold to residents.

This arrangement has a number of advantages over individual PV systems for each apartment:

- installation of a shared PV system on shared roof space avoids equity issues and does not require a bylaw,
- installation of a single larger system may reduce capital costs through economies of scale,
- applying PV generation to the aggregated building load increases self-consumption of onsite generation,
- the size of the aggregated building load may trigger access to a commercial retail tariff at the parent meter, with typically lower volumetric rates (as well as higher fixed or capacity charges).

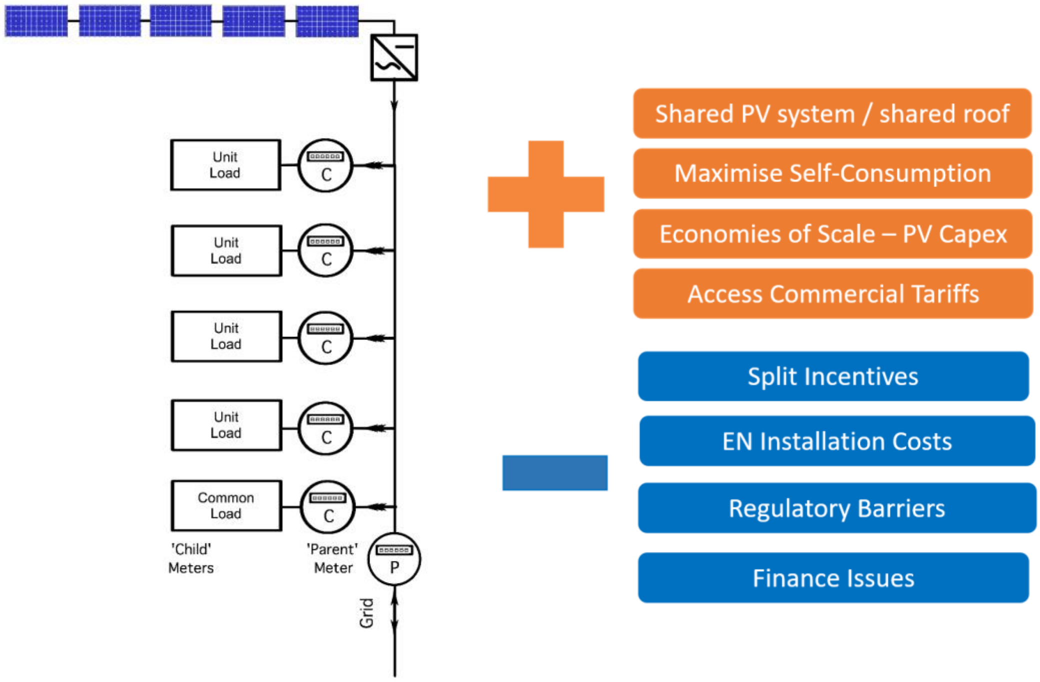


Figure 11 Shared distributed via an embedded network

However, as well as installation of a parent meter, retrofitting an EN may require replacement of all the meters in the building and significant upgrades to existing switchboards and infrastructure, and can therefore be expensive. Costs are highly building-specific and dependent on the requirements of the local Distribution Network Service Provider (DNSP). Some DNSPs, for example, impose significant ‘abolishment charges’ for the removal of existing meters.

Operating costs for an EN comprise electricity costs and charges for metering, billing and compliance. The commercial tariff paid at the parent meter is made up of a regulated network component, dependent on the total annual demand, and a market rate for wholesale and retail charges. Volumetric charges are typically much lower than residential rates, but with significant variability in the market component (typically 9 – 15 c/kWh), often combined with demand or capacity charges. Metering and compliance costs are of the order of $3 and $2 per meter per month, respectively, while billing charges can vary between $15 and $35 per meter per month. The economic benefit of an EN to the strata body therefore depends on the relationship with the ENO, on successful negotiation with the retailer and on effective management of the common property and aggregated apartment load to minimise demand spikes.

There are also significant administrative challenges to establishing an EN. Currently, an exemption framework allows ENO's to onsell electricity to customers, although the process for achieving exemption can be challenging. However, the Australian Electricity Market Commission (AEMC) has recommended discontinuing this framework and restricting EN operation to authorised retailers [18]. Although the intent is to increase consumer protections for EN customers, this is likely to reduce opportunities for smaller, more innovative operators or strata bodies to use an EN as a means of distributing PV generation for the benefit of residents.

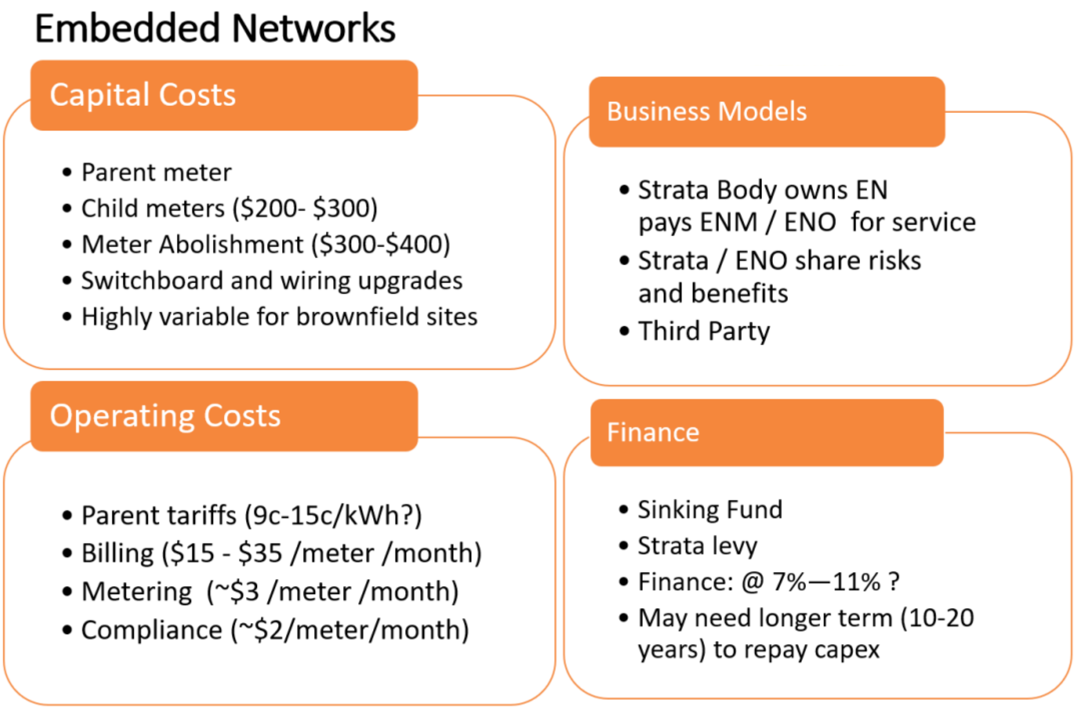


Figure 12 Cost factors for embedded networks

For smaller buildings, the costs and challenges of EN installation are likely to outweigh the benefits, but for larger buildings an EN has the potential to generate considerable bill savings for residents. In low-rise buildings with sufficient rooftop PV potential to make a significant contribution to the building load, PV can increase the customer savings from the EN. However, because PV generation is displacing grid electricity purchased at commercial rates, PV payback periods are generally longer than for typical residential systems.

Despite their potential benefits, ENs are not always operated to the benefit of customers and have been used to lock tenants into disadvantageous long-term energy contracts. A range of potential business arrangements exists – in theory at least - with different levels of risk, benefit and administrative complexity for the strata body. These range from ENOs operating in a purely commercial capacity, taking on the risk and also the benefits of the EN with the strata body and residents simply being customers, to the strata body retaining ownership of the EN and applying for EN and retail exemptions to operate it, employing an ENO on a service basis to provide billing, compliance and administrative support. In between these poles a range of options are possible and establishing the right distribution of risk, cost and benefits between an ENO and the strata body is critical to ensuring owners and residents enjoy the benefits of an EN and shared PV. Some innovative ENOs, ENMs and engineering consultants ([19-21], for example) are working with strata bodies and community housing organisations to facilitate equitable arrangements.

4.5 Shared PV behind the meter

Distribution of generation from a shared PV system to meet apartment loads can also be achieved without the administrative complexity and capital costs of an embedded network. In this shared 'behind-the-meter' (BTM) arrangement (Figure 13), residents retain their existing contract for grid electricity with a market retailer, and purchase PV generation through a solar PPA from a solar retailer via a secondary distribution and metering system.

Because the solar metering system does not require NMI Pattern Approval, it can be retrofitted to existing buildings at relatively low cost compared to an EN. The PPA, which removes the need for owners or the strata body to secure finance for the installation costs, is only applied to PV generation used on site while the FiT from any exported generation is paid to the solar retailer. Residents are able to benefit from the shared PV system according to their daytime usage, but do not receive the additional EN benefit of a reduced tariff for their imported electricity.

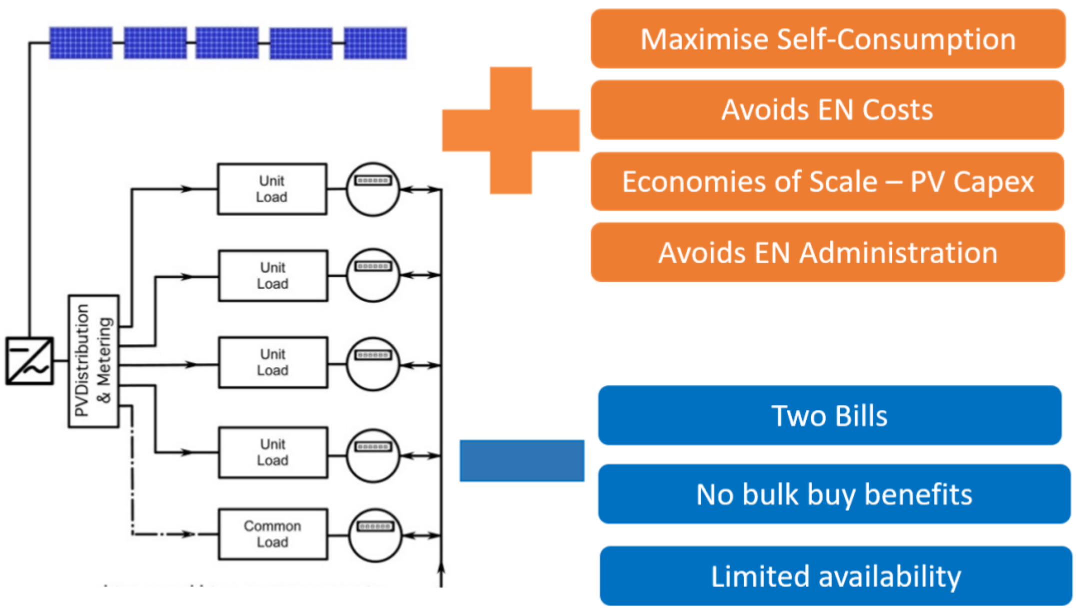
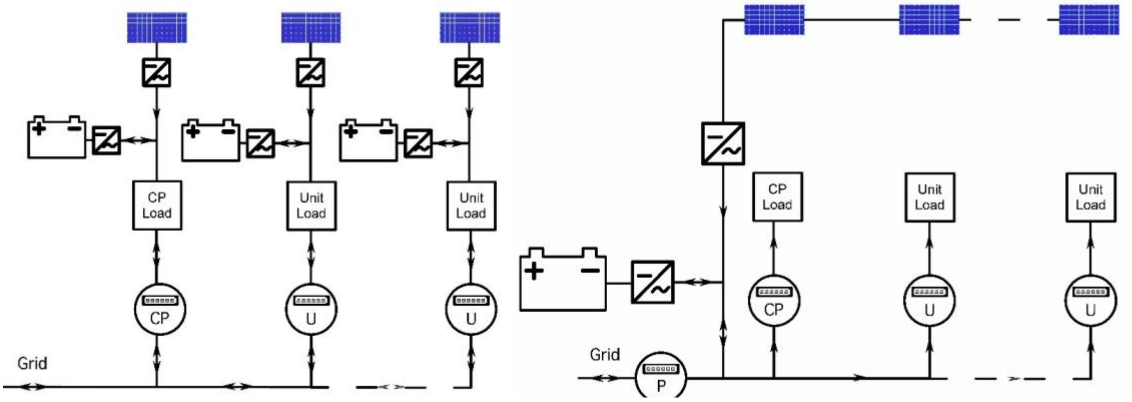


Figure 13 Shared PV distributed 'behind-the-meter'

4.6 Battery energy storage system

A battery energy storage systems (BESS) added to a residential PV system can be used to increase self-consumption of on-site generation, reduce peak demand and shift demand to off-peak periods, thus reducing customer bills. In an apartment building, BESS can be added to individual PV systems for apartments or common property (Figure 14(a)) or as a shared resource to an embedded network (Figure 14(b)), provided a suitable location is available for installation.



(a) Individual behind the meter BESS *(b) Shared BESS in an embedded network*

Figure 14 Possible technical arrangements for PV and BESS

The financial benefits of BESS added to individual CP or apartment PV systems are marginal with battery installation capital costs, even with capital costs repaid over 20 years [22]. The economic case for adding a shared BESS to an embedded network is even less compelling, due to the lower tariffs and lower TOU differential of the commercial tariff payable at the parent meter. Use of shared BESS in apartment buildings is unlikely to be financially beneficial without substantial reductions in capital costs, or targeted government incentives.

Battery Storage (BES) for ENs

Parent Tariff	Control Strategy
High Demand Charge	Peak Demand Shaving
No / low Feed-in Tariff	Increase Self Consumption
High peak / Off-peak Ratio	Demand Shifting

	Individual PV and BES	EN, shared PV and BES
Optimum size	3 – 4 kWh / apartment	~ 1 kWh / apartment
Threshold capex	~ $750/kWh	~ $400/kWh

Figure 15 BESS optimal control strategies, sizes and cost thresholds

4.7 Off-site PV

An alternative approach for apartment residents in buildings with insufficient rooftop potential, or where the organisational and other barriers to onsite deployment are insurmountable or involve significant cost penalties, is for apartment residents to access the benefits of PV generated off-site, either on roofs of other buildings or by ground-mounted arrays, offer opportunities.

- The simplest option is ‘Green Power’ whereby an electricity retailer offsets a customer’s energy use with utility-scale renewable energy, in exchange for a premium retail tariff. This option requires minimal effort from residents wishing to reduce their emissions, but does not offer financial savings;

- An off-site Solar PPA involves the purchase of energy from utility-scale PV generation but differs from Green Power in that the PPA relates to a specific generator. In a ‘Community Solar Garden’, consumers own a share of a solar farm, with a proportion of the PV generated offset against their bill;
- Local energy trading (LET) or peer to peer trading (P2P) enable consumers with PV to sell excess generation to other customers on the distribution network, allowing, for example, apartment residents to buy solar generation from houseowners with rooftop PV.

Under existing network rules, the network charges applied to purchase of off-site PV generation are the same as for generation from any other source, even if the PV is located in the same part of the distribution network. This reduces the savings available through solar PPAs or LET.

5. Decision making for strata bodies

Table 3 summarises the advantages and challenges of each of the PV installation arrangements described.

Table 3 Summary of technical implementation arrangements

Technical Arrangement	Advantages	Challenges	Most suited for
PV for common property	Simplest arrangement: Costs and benefits flow to strata body	Requires agreement of strata body; may underutilise roof space.	High-rise buildings without embedded network
PV for individual apartments	Simplicity	Requires strata by-law; Split incentives; Low self-consumption.	Greenfield sites with equitable pre-allocation of roofspace; Brownfield sites if only one or 2 residents want PV and a bylaw can be passed
Shared PV with embedded network	Increased self-consumption Access to commercial tariffs	Regulatory barriers; Split incentives; Organisational complexity; Interests of ENO and strata body may conflict	Good solution for larger buildings if implemented in interests of residents and owners.
Shared PV 'behind the meter'	Low risk for owners, residents and strata body; increased self-consumption compared to individual systems.	No beneficial tariff arrangements; Residents pay two bills; Limited availability	Brownfield sites where EN costs would be high

The optimum arrangement for any particular building is dependent on multiple site characteristics, including type of building, roof form, roof obstructions and shading, common property facilities, age of the building and electrical installation, demographics and lifestyle of occupants, proportion of renters / owner-occupiers and level of engagement in the strata body. However, the number of apartments has a significant influence on the total building load, while the height of the building will help determine the potential PV capacity per apartment. These two factors are therefore important indicators of which arrangements would be most appropriate, as summarised in Table 4 and Figure 16.

For buildings with reduced roof area (e.g. high rise), installation of a shared PV to meet common property is the simplest and may be the most financially beneficial option.

The viability of an EN is highly building-specific. For buildings with 100 apartments or above, the economic benefits of an EN are likely sufficient to provide significant benefits to the strata body as well as commercial opportunity for the ENO, while retrofitting an EN to a building with less than 30 apartments is unlikely to be cost effective, although the threshold for greenfield sites may be lower. However, onsite generation can reduce electricity costs and the addition of PV can make an EN cost effective for some borderline properties, just as an EN can act as an enabler for PV on others.

Table 4 Optimum solutions for different sized buildings

Number of Apartments	Building Height	Possible Optimum Solution9s)
1 – 30		PV for individual apartments; PV for Common property if high CP load
30 – 100	Low – medium rise	Embedded Network; Shared PV behind the Meter; PV for individual apartments; PV for Common property if high CP load
30 – 100	High rise	PV for Common property; Embedded network with PV
Over 100	Low – medium rise	Embedded network with PV
Over 100	High rise	PV for Common property; Embedded network with PV

Shared BTM PV with a solar PPA may be an economically preferable alternative, particularly for smaller buildings, as the reduced capital expenditure and risk offsets the higher retail tariff. For the smallest apartment buildings, the benefits of shared PV may be less than the costs of additional distribution infrastructure under either model.

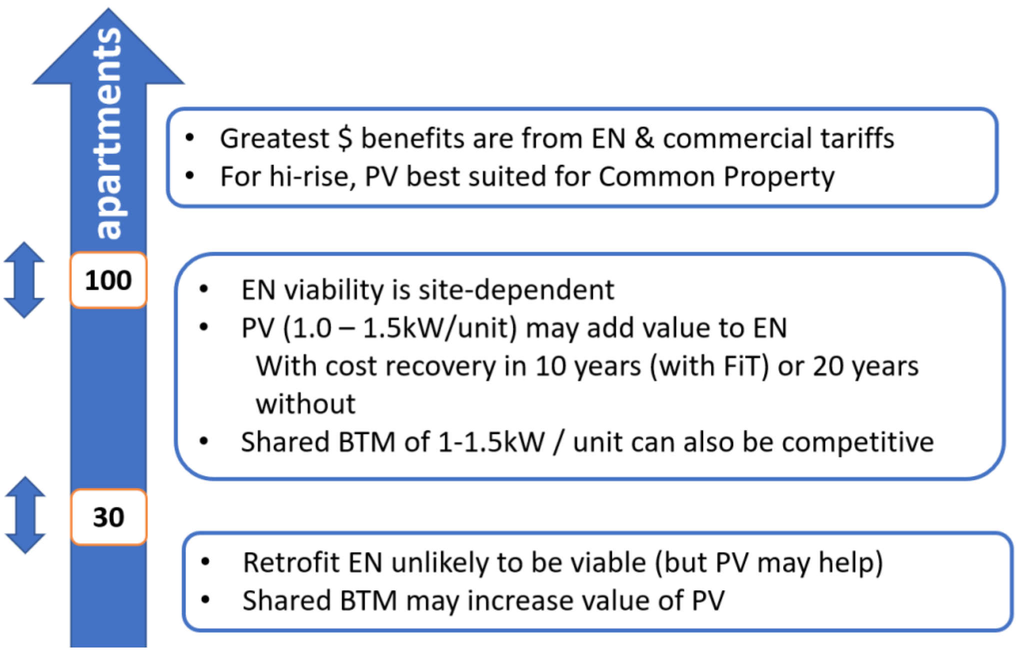


Figure 16 PV deployment for different sizes of apartment buildings

6. Policy recommendations

Although some of the barriers to apartment PV are inherent to the buildings or to the organizational challenges of multi-occupancy living, regulatory policy reform could make a significant contribution to increasing access to rooftop PV for apartment residents.

6.1 Strata law

Some aspects of strata law act to restrict access to solar energy (as well as to other sustainability improvements), creating inequity for apartment residents. Although limited in their scope, legislative changes introduced in some states have demonstrated potential approaches to avoid unnecessary legal constraints on sustainability improvements.

The following changes to state and territory strata laws would help reduce the barriers:

- Exemption of PV installation from the requirement for an Exclusive Use By-Law for individual use of shared roof area. This should be subject to conditions restricting use to a 'fair' share of the suitable area, mandating post-installation roof inspection and allowing only qualified installers carrying insurance against roof-damage.
- A reduced threshold for strata resolutions to allow installation of strata-owned PV on common roof area or for other sustainability upgrades.
- Restrictions on the ground allowed for objections to PV installations or other sustainability upgrades, prohibiting objections on the grounds of physical appearance (similar to the 'ban the banners' amendment in QLD Planning Law [23, 24]).
- Specific inclusion of new sustainability infrastructure in allowable Sinking Fund expenditure
- Allowing strata bodies to use common property as collateral for loans used to upgrade the property, including sustainability improvements, and therefore access lower interest rates

More generally, with tax incentives fuelling property investment and thereby pricing apartment ownership beyond the means of a large proportion of the population, it is questionable whether the processes of strata governance are still fit for purpose. Whilst some laws are drafted with the apparent assumption of house ownership being the default Australian condition, Strata Law seems designed for a community of owner-occupiers which bears little relation to the reality of many apartment buildings. While apartment owners are subject to greater restrictions than house owners, the situation is even worse for the growing numbers of apartment tenants who have no legal role in influencing the strata decisions which govern their daily lives, while managing agents have increasing control.

Although detailed critiques either of strata law or Taxation policy are beyond the scope of this report, there are strong arguments in favour of increasing representation of tenants in strata governance, and of reforming tax arrangements to support higher levels of owner-occupation. Rental tenants are subject to high household electricity bills (and often high CP bills passed on in rental costs) and one of the benefits of allowing them a role in strata decision making (beyond being allowed a representative to observe strata meetings) would be enabling them some degree of control over their energy supply.

6.2 Incentives / finance

Access to finance can be a barrier to strata bodies deploying PV on their buildings, and strata residents are often excluded from incentive schemes for increasing residential PV.

Access to finance could be improved through:

- Reforming legislation to allow strata bodies to use common property as collateral for secured loans towards PV or other sustainability upgrades.
- Local or state government providing or underwriting low-cost finance for environmental upgrades.
- Local or state government providing grant incentives to strata bodies to subsidise installation costs for PV or BESS.
- Local or state government providing grants to strata bodies to cover costs of feasibility studies for PV, embedded networks or BESS installation. (e.g. similar to existing City of Sydney Innovation Grants). Because no two apartment buildings are alike and optimal solutions are building-specific, the need for feasibility grants will continue beyond a few 'early adopter' projects).
- Clarification and simplification of tax regulation to allow strata bodies to generate income from electricity sales to residents without affecting tax arrangements for individual members.

6.3 Energy regulation

As discussed in section 4.4, installing an embedded network (EN) is one way of apartment residents acting together to access renewable energy and reduce their energy bills. It allows residents to combine their electricity usage to 'bulk buy' electricity at commercial tariffs and enables a greater proportion of PV generation to be 'self-consumed' within the building, rather than exporting it to the grid at a relatively low feed-in tariff.

However, where customers are obliged to participate in an EN, there is an opportunity for the ENO to take advantage of a captive customer base, with the result that EN customers sometimes pay higher prices than retail market customers in return for lower standards of service. To address this, and in response to the 'Power of Choice' review [25], policy reform measures have been aimed at increasing access to the retail market for EN customers. The latest AEMC proposals [18, 26] to remove the exemption framework for ENs and restrict the sale of electricity within an EN to authorised retailers are likely to remove some unscrupulous operators from the market, but may also increase barriers to small, innovative ENOs, strata bodies and community organisations aiming to operate ENs for the benefit of residents, including to distribute PV.

Although the AEMC takes the view that "competition remains effective for retail electricity and gas markets in New South Wales, Victoria and South Australia, and … South East Queensland" [27], the ACCC identified that "retail electricity markets in the NEM remain very concentrated" and that "one sign that competition has so far failed to meaningfully challenge the large retailers is limited erosion of their market shares in the past five years.” [28] It is by no means certain that the presence of large retailers in the EN market will automatically reduce bills.

Indeed, by increasing opportunities for existing electricity retailers to operate in the EN market, it may be that changes intended to increase consumer choices could, paradoxically, reduce consumers’ access to innovative business models, diminish their ability to co-ordinate both market engagement and deployment of PV, and consequently reduce their energy choices.

Rather than seeing ENs as inherently contrary to the interests of energy consumers, an alternative approach is to recognize that they can be beneficial but need appropriate regulation. Instead of relying on administrative hurdles and market contestability to protect consumers, existing EN and retail exemption frameworks for establishment of an EN should be retained, with specific exemption class(es) for residential strata bodies or community energy organisations owned by or constituted to benefit consumers, while strengthening protection for residential customers.

Increased regulation to protect EN customers should include effective and meaningful price control, with prices tied to discounted average market tariffs (instead of standing offers as at present). The distinction between strata bodies acting on behalf of developers and those comprising individual apartment owners is an important one, although they have equal legal standing. The length of service contracts between developers and ENOs should be limited, and restrictions placed on the incentives offered to developers by ENOs or retailers, though enforcement may present challenges.

Current metering rules are also problematic. The cost and complexity of transferring meter ownership results in unnecessary churn with additional costs for consumers. Moreover, as increasingly high-quality, high precision metering equipment with high temporal resolution and versatile connectivity is available, the cost of metering hardware is artificially inflated by an NMI Pattern Approval process which stipulates redundant functionality.

Finally, a range of opportunities for apartment residents, including use of local energy trading or peer to peer selling arrangements (whether between prosumers in a single building or strata complex or to allow residents to access PV generation from a solar garden) are hampered by current network pricing arrangements. A move towards effective cost-reflective pricing of the local distribution network could increase opportunities for DER deployment, including on apartment buildings, with potential benefits for networks (through deferred augmentation) as well as for consumers.

7. Conclusion

There is a clear and significant opportunity for deployment of rooftop PV on Australia's apartment buildings, which could contribute an estimated 2.9GW – 4.0GW of peak power capacity to the electricity network, reduce household bills, increase equity for the growing proportion of Australians living in apartment buildings, and may also reduce grid augmentation costs and so contribute to savings for *all* electricity users.

The technical, financial, organisational and regulatory barriers that have hitherto largely prevented this deployment are by no means insurmountable, but neither are the solutions simple and there is no single implementation model will work for all buildings.

Sharing PV generation and applying it to aggregated building loads increases self-consumption and can create additional value for residents, whether distributed through an embedded network or a separate behind-the-meter distribution arrangement. Embedded networks have higher capital costs, particularly when retrofitted to existing sites, but, for larger buildings, can maximise customer benefits through access to lower tariffs, if the business model can overcome administrative barriers and operates in the interests of residents and owners. However, costs and benefits are highly building-specific and, for some buildings, smaller systems applied to common property or to individual apartment loads, or off-site generation, may be preferable.

This research highlights an important role for policy in supporting increased PV deployment on apartment buildings. As much as the Strata Laws governing apartment buildings need to adapt to changing circumstances and to increasing sustainability priorities, greater consideration of multi-occupancy buildings is also needed throughout many other areas of legislation. For apartment residents, accessing the benefits of renewable energy, like many other aspects of medium- and high-density living, requires co-ordination. While residents have been ill-served by embedded networks in the past, new business models for combining ENs with solar PV, operated in the interests of apartment owners and residents, are emerging and in need of incentives and regulatory support.

An inclusive energy transition needs to move beyond a narrow vision of individual market engagement to facilitate and encourage such co-ordinated engagement of energy users.

Customers and strata bodies need comprehensive and unbiased information to help them navigate the available options, and it is hoped that the open-source tool developed through this research can contribute.

Further research is needed, particularly in assessing the potential benefits of increasing self-consumption through managing and shifting loads (including water heating, air-conditioning and electric vehicle charging), analysing the impact of a wide range of possible future financial settings and reviewing international best practice to develop legal and social settings for new collaborative business models.

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Appendix A: Publications and further information

More detail of the analysis described in this report, particularly regarding the methodology, results and regulatory environment and policy implications can be found in the following publications, from which much of the content of the report has been taken:

Roberts, M.B., *The value of co-operation: Opportunities for deployment of distributed rooftop photovoltaics on Australian apartment buildings*, (PhD Thesis) 2019, University of New South Wales: Sydney.

Roberts, M.B., A. Bruce and I. MacGill, *Opportunities and barriers for photovoltaics on multi-unit residential buildings: Reviewing the Australian experience.* Renewable and Sustainable Energy Reviews, 2019. **102**: p. 95-110.

Roberts, M.B., A. Bruce and I. MacGill, *A comparison of arrangements for increasing self-consumption and maximising the value of distributed photovoltaics on apartment buildings.* Solar Energy, under review.

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Where copyright allows, these publications can be downloaded from the Centre for Energy and Environmental Markets website at ceem.unsw.edu.au/publications.

Appendix B: Case studies

Case study W

Number of Apartments: 72 in three buildings

Metering Installed: 44 apartments plus common property (3-phase) and whole-of-site (3-phase)

Six different arrangements were modelled:

- Business as Usual *(bau)*
- PV for common property load only *(cp_only)*
- Individual PV systems for each apartment *(btm_i)*
- Embedded network *(en) without PV*
- Embedded network with PV *(en_pv)*
- PV shared behind the meter with a solar PPA *(btm_p)*

Figure W1 shows the potential total annual savings[4] for the building under each arrangement, using the optimum PV system size for each arrangement, if capital costs are repaid over 20 years, and with assumed financial settings).

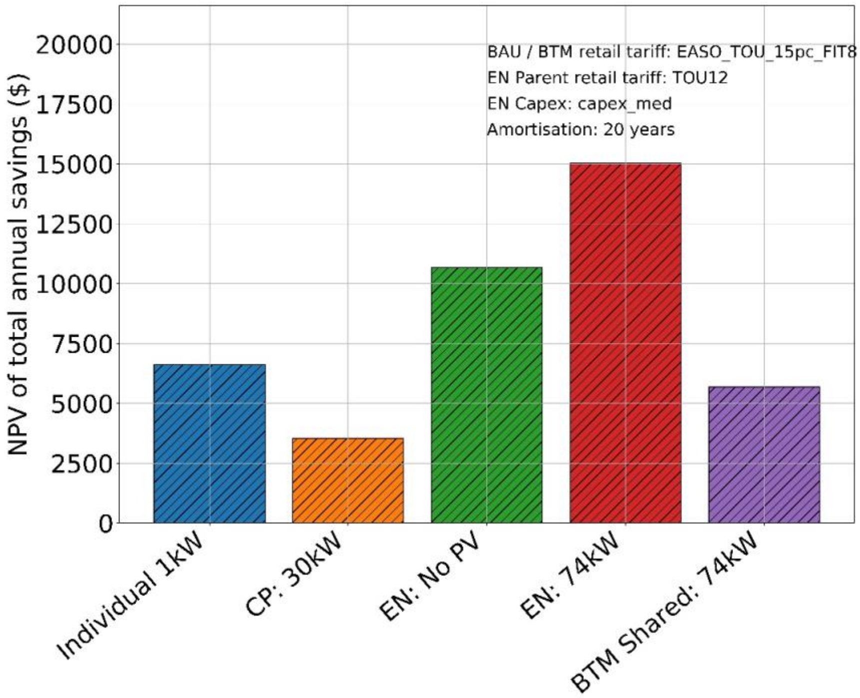

Figure W1 Comparison of technical arrangements for case study W

W.1. Solar PV for common property only

Installation of a PV system by the Owners Corporation to meet common property load is the simplest solution. Two systems were considered: 30kW and 15kW, installed on North-facing roofs, with estimated capital costs of $18150 and $33600 respectively.

With a typical time of use tariff, the 30kW system gives the greatest annual savings,

[4] Savings are calculated on a Net Present Value basis (i.e. allowing for the decreased future value of money) with a discount rate of 6% pa. Future increases in electricity prices have not been included.

except where no feed-in-tariff (FiT) is available from the retailer and capital costs must be repaid within 5 years. With the larger system and a FiT of 12c/kWh, estimated annual savings for the OC are $4,100 with capital repayment over **10 years**, or $1,900 with repayment over 5 years (and greater savings for the remainder of the system lifetime)[5].

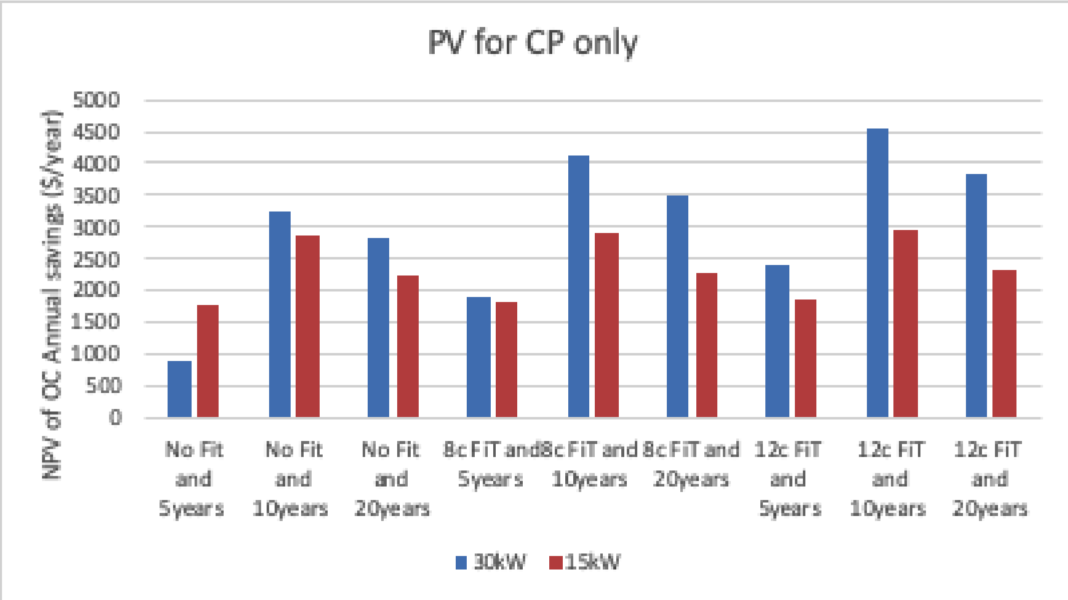

Figure W2 Annual savings for Strata Body with 30kW PV system applied to common property

W.2. Individual PV systems for apartments

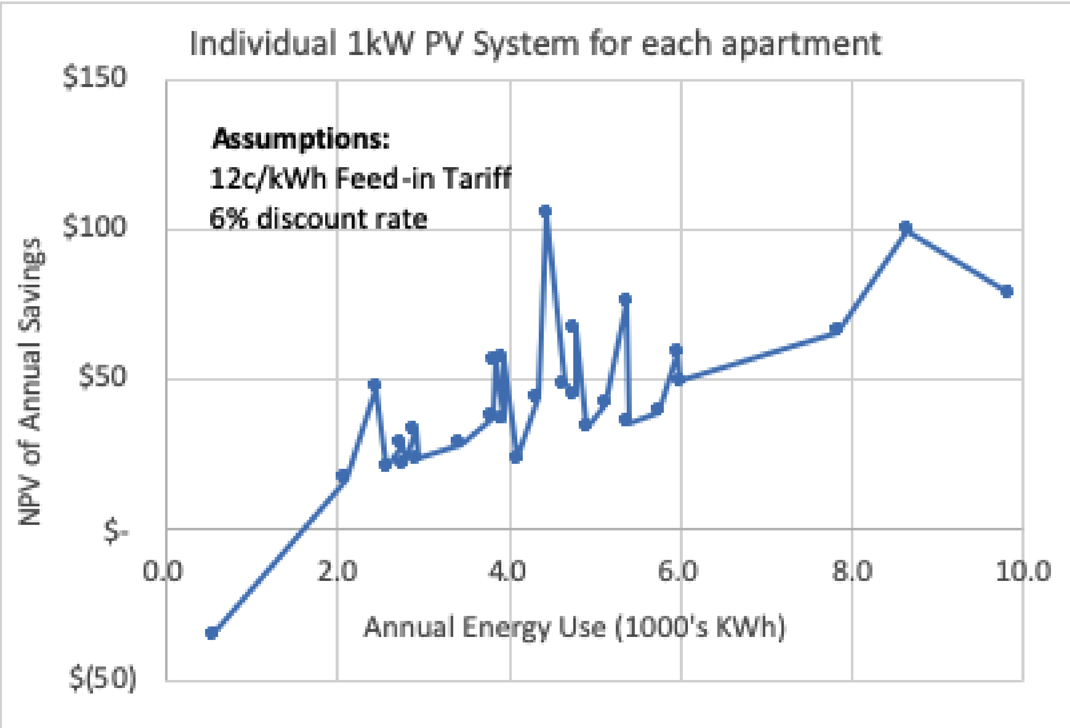

Figure W3 Annual savings for households with 1kW PV system

[5] Savings are calculated on a Net Present Value basis (i.e. allowing for the decreased future value of money) with a discount rate of 6% pa. Future increases in electricity prices have not been included.

W.3. Embedded network with PV

Installation of an embedded network (EN) has the potential to create the biggest savings for The Manor residents. Adding a shared PV system to the embedded network could increase the savings significantly.

The savings from an EN are dependent on a large number of variable cost factors:

- Capital costs for PV System installation. This is estimated at $84,000 for a $74,000kW system (based on average NSW cost for commercial systems[6]) including GST and STC rebates. There may be additional costs for access equipment for installation and for grid protection costs due to the size of the installation.
- capital costs for installation of the EN (which may include upgrades to the switchboard and meter rooms). These are estimated at between $30,000 and $80,000. A figure of $48,000 was used for the modelling shown.
- operating costs of the EN, the commercial tariff for 'bulk-buying' electricity for the whole building (agreed by negotiation with a retailer),
- the cost of borrowing and the period allowed for repayment of capital costs.

Three potential PV systems were modelled: one using the whole roof area (143kW), one using north and west facing roofs (109kW), and one using north facing roofs only (74kW).

The greatest savings are generated by the 74kW PV system, with an estimated capital cost of $84,000 (based on typical NSW installed costs, but excluding the cost of grid protection required for all systems above 30kW). Over twenty years, we estimate potential savings across the building of $13,000 - $16000 per year, on a NPV basis. A range of business models are possible with the risks, costs and benefits of the embedded network and the PV shared in different ways between the ENO, the Owners Corporation, apartment owners and residents.

Residents cannot be obliged to join an embedded network and must be able to opt out at any time. The electricity tariff charged to EN customers therefore has to be competitive with a market retail tariff, to encourage participation from all residents. It may also be beneficial to design the tariff to encourage residents to use cheap daytime solar electricity.

Figure W4 shows estimated annual savings for each metered household, plotted against their total annual energy use, for an embedded network with two potential internal tariffs. The red line shows an internal EN tariff equivalent to the retailer standing offer TOU tariff with a 20% discount applied. The blue line shows a 'solar TOU' tariff which has an additional off-peak period between 10am and 2pm (to encourage residents to use the cheap daytime solar generation). Note that residents with higher energy use make higher savings, but with the 'solar TOU' tariff, greater savings can be achieved by moving energy use to the middle of the day. The average net annual income available to be shared between the Embedded Network Operator and Owners Corporation is approximately $156 per customer for the TOU tariff and $124 per customer for the 'solar TOU'.

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[6] https://www.solarchoice.net.au/commercial-solar-power-system-prices

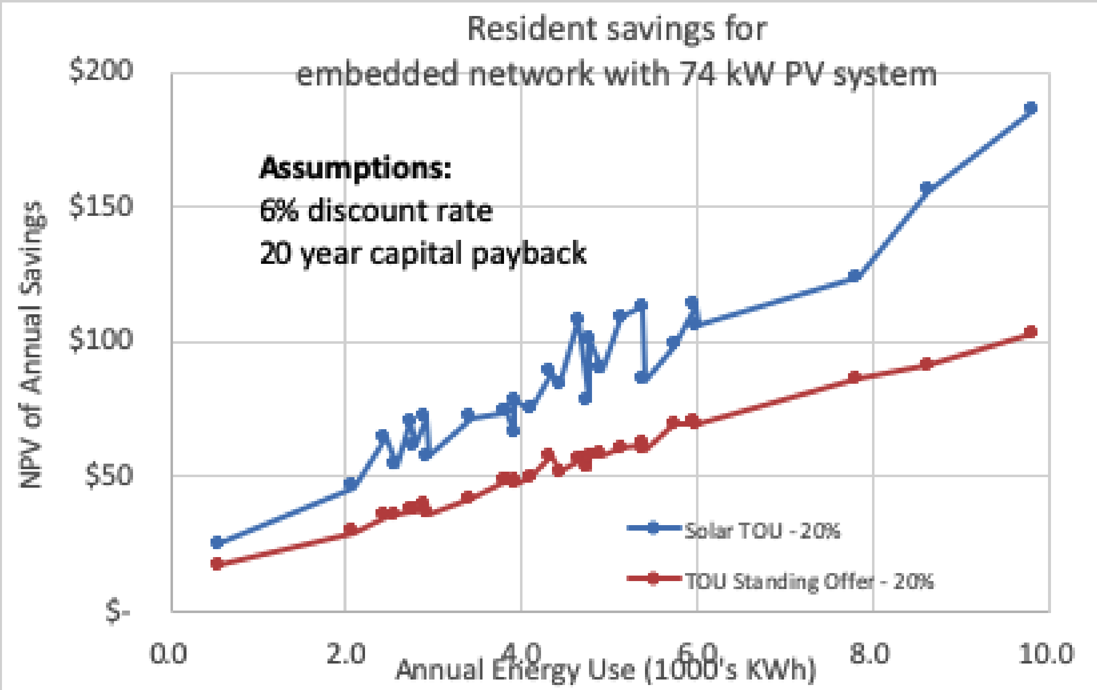

Figure W4 NPV of Annual household savings in EN with 74kW PV under different tariff arrangements

Addition of a shared battery to the EN can further reduce electricity bills, but at current capital costs, it would not be cost effective, even with repayment over 20 years.

W.4. Shared PV 'behind the meter'

To avoid the administrative complexity and potentially high installation costs of an embedded network, a shared PV system could be installed with a secondary metering arrangement to distribute the solar generation 'behind the meter'. Each resident would keep their existing retail electricity arrangement and enter into a 'power purchase agreement' with a solar retailer (e.g. Allume Energy) for cheap PV generation. Figure W5 shows potential savings for the 28 metered households under this arrangement. Note that this arrangement is new to the market and may not be available, while the terms of the PPA will be at the discretion of the retailer and may be less advantageous than those modelled here.

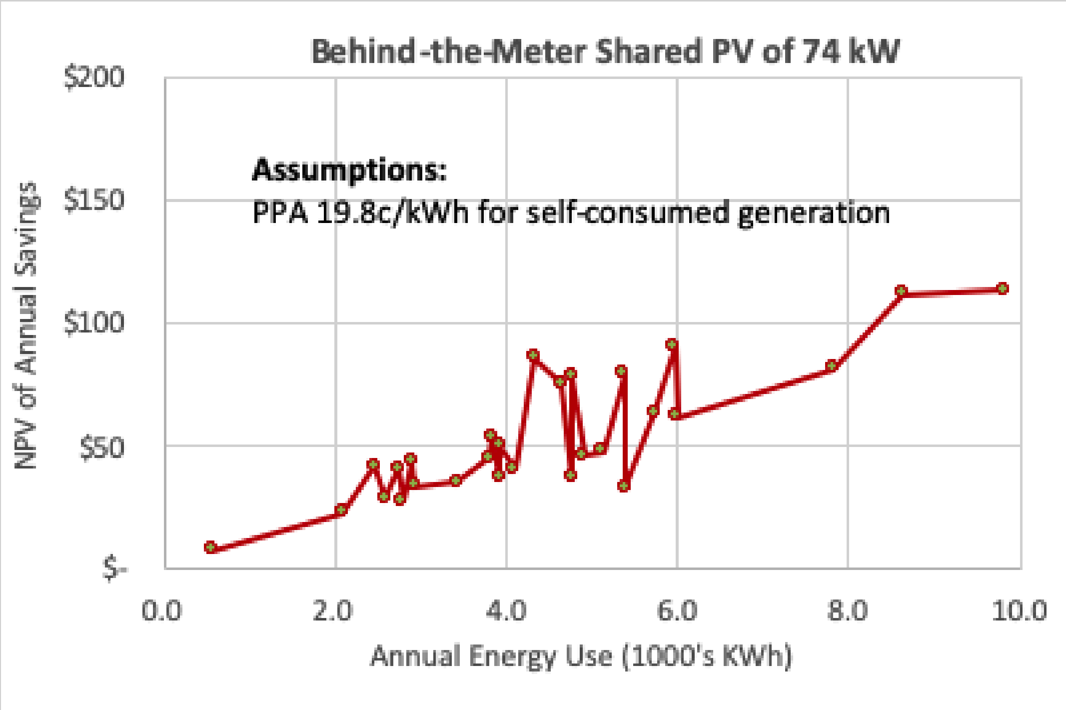

Figure W5 NPV of Annual household savings with shared behind-the-meter PV on a solar PPA

W.5. Summary

- A PV system of 30kW installed to meet common property demand at an estimated cost of $34,000 (inc. GST and STC rebates, but excluding access costs and grid protection if required) is the simplest option and would generate savings for the OC even with capital costs repaid over 5 years.
- An embedded network with PV of 74kW would cost between $110,000 and $200,000 and could generate the greatest savings for householders over the longer term, dependant on how the risks, costs and benefits are shared between the OC and the Embedded network Operator, but there are administrative complexities in applying for retailer and EN exemptions.
- A ‘behind the meter’ sharing arrangement with a solar PPA could also generate savings for households and is worth further exploration.

Case study T

Number of Apartments: 15

Metering Installed: 11 apartments plus common property and whole-of-site

T.1. Solar PV for common property only

Installation of a PV system by the Owners Corporation to meet common property load is the simplest solution. Common property load for the building is low (less than 4MWh/year), so relatively small PV systems (1,2 and 4kW) were modelled, using a typical time of use tariff.

With no feed-in-tariff (FiT), only the 1kW system gave modest savings over ten years. With a FiT of 8c/kWh, however, the 4kW system gives the best outcome, with annual savings of approx. $200 (on an NPV basis over 10 years).

T.2. Comparison of PV arrangements for apartments

Four different arrangements for supplying PV generation to apartments were modelled and compared to Business as Usual *(bau)*

- Individual PV systems for each apartment *(btm_i)* (2.0kW / unit)
- Embedded network *(en)*
- Embedded network with PV *(en_pv)*
- PV shared behind the meter with a solar PPA *(btm_p)*

Figure T1 shows the estimated potential total annual savings for the building under each arrangement, using the optimum PV system size for each arrangement if capital costs are repaid (top) over 20 years (on an NPV basis with a discount rate of 6%), and (bottom) over 10 years.

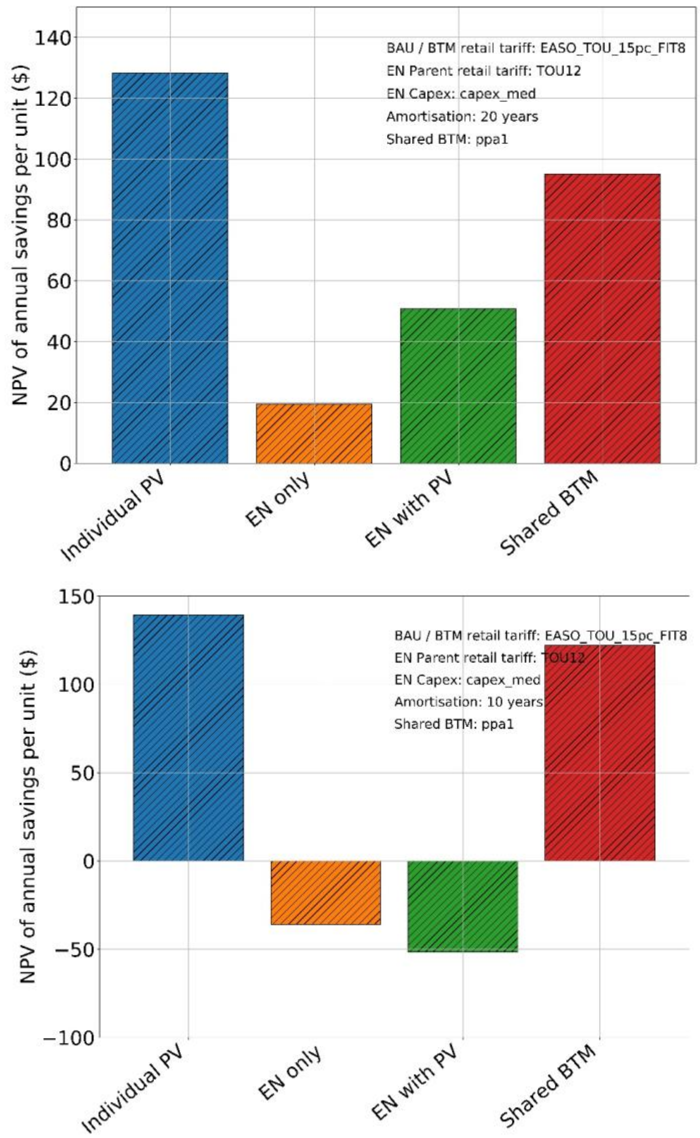

Figure T1 Comparison of technical arrangements for case study T
With capital costs repaid over 20 years (top) and 10 years (bottom)

The installation and administrative costs of an embedded network, shared between a small number of apartments, is likely to make an embedded network the least cost-effective option. To avoid the administrative complexity and potentially high installation costs of an embedded network, a shared PV system could be installed with a secondary metering arrangement to distribute the solar generation 'behind the meter'. Each resident would keep their existing retail electricity arrangement and enter into a 'power purchase agreement' with a solar retailer (e.g. Allume Energy) for cheap PV generation. However, the terms modelled here may not be available given the small size of the building, as the benefits for the solar retailer would be marginal over the medium term.

All apartments would benefit from individual PV systems of 1.5kW – 2kW. The NPV of annual savings are shown in Figure 3, assuming repayment of capital costs over ten years (with an assumed discount rate of 6%) on a typical time-of-use retail tariff with a feed in tariff (FiT) of 8c/kWh paid for excess generation exported to the grid. Greater benefits would be available, particularly for apartments with lower energy use, if a higher FiT can be accessed, or if lower installation rates can be achieved through a group purchase.

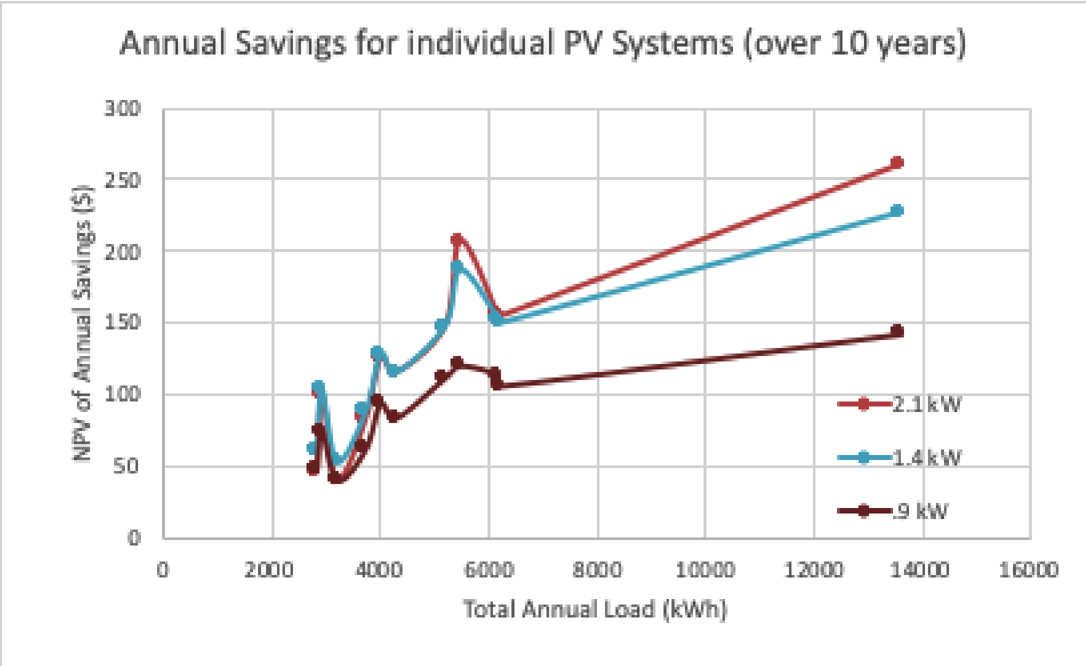

Figure T2 Annual savings for households with individual PV systems