DIGITAL SOLAR AND STRATA

A Feasibility analysis for South East Queensland

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TABLE OF CONTENTS

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EXECUTIVE SUMMARY:

This report investigated the feasibility of Digital Solar for implementation in strata buildings across South East Queensland. Digital Solar is an emergent technology that is as of yet unapplied to the strata marketplace. It combines intelligent metering and energy tracking with a sophisticated cloud analytics and billing platform. Digital Solar facilitates the sale of solar energy between multiple parties and is able to analyze usage information to bill each user based on their consumption. As such, the technology addresses many of the key landlord-tenant concerns that have thus far prevented solar adoption in strata. By enabling the sale of solar energy to multiple parties, a greater proportion of building grid-consumption can be offset, allowing the rate of grid feed in at low prices to be minimized. In this respect, Digital solar can reestablish the incentives for strata to install solar panels that make the most of available roof space and whole-of-building energy consumption.

This investigation was framed based on current climate risks, the state of Australia's energy market and the future energy market transitions that could ensure energy sustainability. Digital Solar was assessed against four separate criteria:

1. The contribution of Digital Solar to an increase in the viable size of solar installed on a strata property
2. The environmental benefits and considerations of the technology
3. The economic and financial feasibility of the technology
4. Its contribution to the wider transition towards distributed energy systems

Digital Solar was proven to lead to significant increases in the viable size of solar that can be installed on strata buildings, without increasing the rate of feed-in to the grid. The technology has the potential to drive greater adoption and larger installations of solar in strata buildings. Several factors influence the relative increase in system size that Digital Solar enables at a given property, but the key driver of this was the difference between common area and residential load profiles.

A number of environmental benefits were realized through the installation of Digital Solar, largely because it enables the use of larger solar systems, and can thus increase avoidance of fossil-fuel based grid consumption. A 288% increase in lifetime emissions abatement occurs with the installation of Digital Solar, but there is minimal impact on energy payback time. Further studies will be required to fully determine the social cost of abatement.

Financially, the feasibility of Digital Solar was highly variable between each of the study sites. 60% of Digital Solar projects were determined to be financially feasible based upon project NPV. Under the scenario assumed, residents received the highest average benefit of any party involved. Payback period for Digital Solar is longer than that of standard solar installations; the shortest recorded in the study was 9.43 years. In some cases, the costs of Digital Solar far outweighed the additional financial benefits it provides.

Digital Solar makes some valuable contributions to the distributed energy transition and has the potential to increase the adoption rate of solar PV technologies. The system can overcome some of the structural barriers constraining adoption for individuals who install the system, but has the potential to place disproportionate social costs on those who do not or cannot adopt the system. Digital Solar drives increased energy distribution but not necessarily increasing energy democracy, and therefore does not realize the full benefits of distributed generation.

Table 1: Key Report Findings

Pillar	Key Findings
1: The contribution of Digital Solar to a size increase	1. Digital Solar can potentially lead to a significant increase in the installed size of solar in strata by allowing the sale of energy to both common and residential areas. 2. The difference between common area energy usage and residential energy usage is strongly associated with the increase in solar size achieved by Digital Solar. 3. Installation of Digital Solar will require accurate load profile data that is difficult and/or time consuming to acquire. 4. Increasingly large solar installations could have a range of negative impacts on the energy market including increased electricity rates
2: Environmental Performance and Considerations	1. Digital solar, by enabling the installation of larger solar systems can result in significant emissions abatement. 2. Energy Payback period did not vary significantly between standard and Digital Solar installations. 3. In 60% of cases, the private costs of emissions abatement were negative, indicating that this environmental benefit was achieved at a profit. 4. Distributed, large solar installations on rooftops are environmentally preferable to centralized solar PV generation. 5. Australia is in need of a solar panel recycling policy to manage the potentially negative end-of-life impacts of the technology.
3: Economic and Financial Feasibility	1. Digital Solar proved to be financially feasible in 60% of cases 2. In some cases, it may not be optimal to install the largest Digital Solar system possible 3. Adjustment of fee structure is a key way to improve financial performance 4. A low grid price or bulk-billing agreements can constrain the returns received by Trust investors 5. Future studies should examine financials under different scenario's and conduct sensitivity analysis to establish factors that consistently impact financial performance
4: Contribution to the Distributed energy transition	1. Digital Solar leads to advances that are important in tackling some of the structural issues preventing the move towards distributed energy 2. Digital Solar increases independence from the grid which may provide benefits to users but could place a net social cost on non-adopters and increase fragmentation in the energy market 3. The legal complexity of implementing Digital Solar in strata buildings reduces the contribution towards achieving energy democracy 4. Digital Solar does little on its own to address the wider technical and physical issues that limit distributed adoption

	5. Working in concert with other technologies such as in Virtual Power Plants, Digital Solar can play an important role in transition of the market to a distributed model and increased energy democracy

GLOSSARY:

Abatement Project: A project that will reduce a building's greenhouse gas (GHG) emissions.

Abatement Cost: Represents the lifetime cost per tCO_2e abated by an energy efficiency or environmental project.

Greenhouse Gas (GHG): The atmospheric gases responsible for causing global warming and climate change. The six Kyoto Protocol classes of greenhouse gases are carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydro- fluorocarbons (HFCs), per- fluorocarbons (PFCs) and Sulphur hexafluoride (SF6).

Discount Rate: The discount rate is used to account for the diminishing value of money over time. Discount Rate is an integral part of calculating NPV.

tCO_2e: Tons of carbon dioxide equivalent, is a measure that allows for comparison of the emissions greenhouse gases relative to a unit of CO2. The figure is calculated by multiplying the greenhouse gas's emissions by its 100-year global warming potential.

Project Lifetime: The number of years that a project is able to achieve emissions reductions. For photovoltaic solar panels, this is assumed to be 25 years.

Net Present Value (NPV): The total value of a project given in 'present day' dollar values. It is the total cost of the project over its lifetime less all anticipated savings, with a discount factor applied to account for the time value of money.

Photovoltaic Solar (Solar PV): Solar cells, also called photovoltaic (PV) cells, convert sunlight directly into electricity, rather than by using thermal energy of sunlight.

Strata: A given set of laws and building management policies that allow for collective ownership of common areas and individual ownership of apartments. See section 2.3 for further detail.

Feed-In-Tariff (FIT): A feed-in tariff is a rate paid for electricity fed back into the grid from a renewable generation source such as a rooftop solar panel or wind turbine.

Owners Corporation: The owner's corporation is the body made up of all the owners in the strata scheme. It has the responsibility for: maintaining and repairing the common property of the strata scheme, managing the finances of the strata scheme and taking out insurance for the strata scheme.

National Energy Market (NEM): The National Electricity market commenced operation in 1998, and acts as the wholesale spot market for electricity produced in five states - Queensland, New South Wales (including the Australian Capital Territory), Victoria, South Australia, and Tasmania.

Australian Energy Market Operator (AEMO): The entity that manages the NEM market, oversees electricity transmission and manages network security.

Load Profile: A load profile is a graph of the variation in the electrical load versus time. A load profile will vary according to customer type (typical examples include residential, commercial and industrial), temperature and weather conditions.

Common Area: Areas of a strata building not under individual ownership, such as foyers, lifts, stairwells and pools.

1.0 INTRODUCTION

Climate change is a defining challenge of the 21st century. The recognition of its effects, and the linking of these to human based activities now approaches scientific consensus. As such, humanity must now collectively face the dual challenges of both adapting to climatic effects as they unfold and mitigating further degradation of planetary systems.

Energy systems lie at a crossroads between environmental degradation, economic prosperity and social development, and as such are a key challenge to address for both climate change management and sustainable development. Increasingly, climate experts, politicians, think tanks and economists point to the need for fundamental structural adjustment of earth's energy systems (IPCC 2014).

Globally, structural shifts in the energy market have been varied. More often than not, policies drafted to manage the transition have often resulted in insufficient action, contained poorly defined requirements, and done little to address the structural changes required to alter the way that economies produce and consume energy (Huitema et al 2014). Whilst progress in international agreements to limit emissions is progressing (for example, with the ratification of the Paris Accord 2015), these policies are not specifically targeted at the transition of energy systems and avoid prescribing specific strategies for emissions reduction.

At a local level, policy instruments such as the Renewable Energy Target have been effective at increasing the proportional contribution of renewable energy to national electricity supply. However, these policies have done little to transition energy markets to a new, more efficient model of operation, and instead simply 'graft' renewable generation onto the existing market model and ageing grid infrastructure (Stock 2015). Furthermore, the RET has garnered widespread criticism by disproportionally placing financial burned of increased renewable adoption on those who do not or cannot adopt the technology (Centre for International Economics 2013).

As is recognised by prominent economist Jeremy Rifkin, true energy sustainability will require more than just greater use of renewables, but instead a transition to an entirely new 'distributed power' model. Under such a model, centralised power plants are replaced by localised energy generation, sale and sharing of power between many parties and increased renewable use (Rifkin 2011). Distributed generation offers substantiated emissions reductions and the true social, economic and environmental benefits of renewable technologies are able to be realised (Rifkin 2011).

Much of the progress towards realising a future of distributed generation has occurred within the green energy and innovation sectors. This report will investigate one such innovation; Digital Solar. A new technology that combines advanced metering, data analysis and cloud billing services, it has the potential to drive increasing solar adoption in the rapidly growing strata property market. This report will investigate the feasibility of Digital Solar when applied to 10 multi-tenant residential strata buildings in Queensland. Currently, solar adoption in the strata market has been constrained by issues with shared ownership, lack of available frameworks and poor pricing incentives.

Digital solar will be evaluated based on four separate criteria or 'pillars', which cover:

1. The contribution of Digital Solar to an increase in the viable size of solar installed on a strata property
2. The environmental benefits and considerations of the technology
3. The economic and financial feasibility of the technology
4. Its contribution to the wider transition towards distributed energy systems

This report will form important groundwork in determining the role that Digital Solar can play in increasing solar adoption and the transition to a more distributed and collaborative green energy network.

2.0 BACKGROUND

2.1 THE NEED FOR CLIMATE ACTION

This section presents a brief overview of the key drivers, vulnerabilities and threats that climate change poses in the Australian context. Whilst the focus of this report is not specifically on climate change, it is important to reiterate the fundamental challenges that renewable energies and companies such as Wattblock aim to address.

For a more comprehensive overview of Climate Change and sustainability, it is recommended that readers consult the IPCC Climate Change 2014 Synthesis Report.

Climate Change describes the changes in average weather conditions at a particular location (Climate Consensus 2013). In recent years, it has come to describe the rapid alteration of Earth's climatic processes due to anthropogenic emissions of greenhouse gases, such as CO2. Though gradual change in Earth's climate is a natural process, the observed rate of change currently far exceeds any observed in past climate modelling. This causes disruption of large scale climate, biological and planetary systems (IPCC 2014).

The Intergovernmental Panel on Climate Change (IPCC) in its 5th assessment report details the changes due to climate change that have already been observed, or are likely to be witnessed in the coming century. Climate Change can have impacts outside purely environmental dimensions, but also impact on Social and Economic factors. A summary is presented below in table 2.

Table 2: Frequently cited impacts of climate change (IPCC 2014).

Frequently Cited Impacts of Climate Change
1. **Increased stochasticity of large scale weather patterns and oscillations** 2. **Increasing intensity/severity of weather events** 3. **Sea level rise** 4. **Mass species extinction** 5. **Less reliable water supply** 6. **Less reliable agricultural yields** 7. **Changes to hydrological cycle** 8. **More 'extreme heat' days per calendar year** 9. **Ocean acidification and sea temperature increases** 10. **Rapid change too natural ecological and geophysical processes** 11. **Melting ice caps** 12. **Changes to disease distribution** 13. **Mass climate induced migration**

Globally, Australia is a highly emissions intensive country, and has the highest emissions per capita of any nation on Earth, as indicated in figure 1.

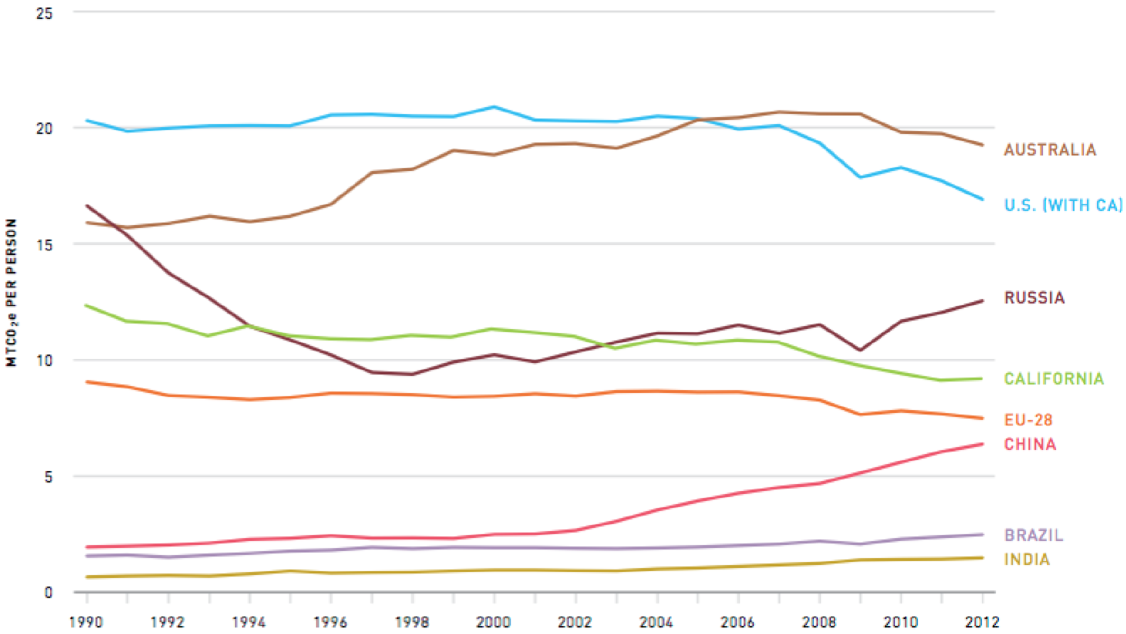

Figure 1: Emissions per capita in Australia compared to other nations (Next 10 2016).

Although Australia has recorded emissions declines since 2006 (falling from 614 Mt CO_2e in 2006 to 559 Mt CO_2e in 2012), absolute emissions are projected to increase to 724 Mt CO_2e by 2030 (Department of Environment 2015). This will be driven by a 30% increase in energy consumption by 2050, due to population growth (Flannery & Sahajwalla 2013).

These statistics indicate that the emissions reduction potential within Australia's energy sector are substantial. It is essential to find ways to drive a transition towards green and distributed energy networks in order to sustainably meet growing demand and limit the effects of climate change.

2.1 ENERGY IN AUSTRALIA

This report investigates the feasibility of an emerging green energy technology. As such, it is important to provide background on the current state of the Australian energy market as a whole. This section provides a brief overview of the market as of late 2015.

The Australian energy market is currently in a state of uncertain transition. An ageing network infrastructure is becoming outdated as new renewable technologies emerge and consumer electricity demand plateaus. The complexity of the market itself is also increasing as individuals are able to become their own energy producers.

For the past 5 years, average energy consumption has been steadily declining at a rate of 1.7% per annum. This is driven by the downturn of several industrial operations (2 aluminum smelters have closed in the last 5 years), as well as changes to consumer energy demand because of rising electricity prices and renewable subsidies (Australian Energy Regulator 2015). Electricity consumption is projected to grow from 2016-2018 at a rate of 3.1%, largely as a result of Queensland LNG operations. Residential demand is expected to experience moderate growth, as population expands and electricity prices decline, driving further consumption. Likewise, peak electricity demand has also exhibited decline (Australian Energy Regulator 2015). These declines are largely responsible for poor investments in network infrastructure and generation capacity. As the networks age, increasing amounts are spent on grid maintenance which is driving a rise in the operating inefficiency of the national grid infrastructure (Stock 2014). In Victoria, NSW and South Australia, demand was 20% lower than the historical peaks recorded in 2009. Queensland remains an exception however, with increasingly large demand peaks predicted in the future (see figure 2). Peak demand growth is expected to increase more rapidly than actual energy consumption, increasing the viability solar PV installations because of their ability to help manage and shave peak usage (Australian Energy Regulator 2015).

	QUEENSLAND	NSW	VICTORIA	SOUTH AUSTRALIA	TASMANIA
Change from 2013–14 (%)	6.0	–1.2	-16.2	-14.5	1.1
Change from historical maximum (%)	0.4	–19.6	–17.7	–17.4	-7.2
Year of historical maximum	2014–15	2010–11	2008–09	2010–11	2008–09

Figure 2: Change in electricity demand across states in the NEM (Australian Energy Regulator 2015).

Though coal is still the predominant source of electricity in Australia (and is likely to remain so for some time due to its ability to supply base load), the generation mix is becoming increasingly diversified as renewable technologies decline in price, and schemes such as the Renewable Energy Target (RET) persist. This is reflected in figure 3 below, which shows the varying generation mix for each state. In particular, wind power has exhibited strong growth of 270megawatts in additional capacity in 2014-2015 alone; an 8% increase (Australian Energy Regulator 2015). The AEMO projects that the majority of new energy generation investment over the next 20 years will be in wind (AEMO 2016). Not all renewable sources are growing though, as hydro has shown declines in output of 30% in 2014-2015, due to poor rainfall and water shortages (Australian Energy Regulator 2016).

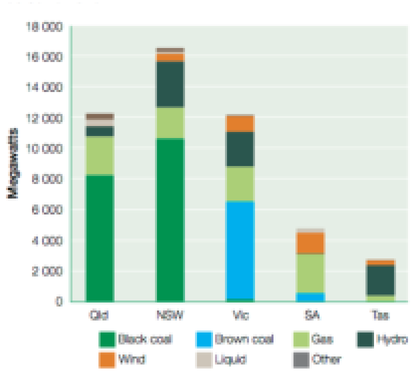

Figure 3: Energy generation mix of each state in the NEM (Australian Energy Regulator 2015).

Falling prices continue to drive strong growth for solar PV across Australia (see figure 4 below). More than 1.5million households have now installed solar, allowing it to account for 8% of total NEM generation capacity (Clean Energy Council 2015) Though the installation rate of solar PV is falling, average system size has increased from 2.5kw in 2011 to 4.8kw in 2015. AEMO projections indicate that solar installations will triple by 2030, when solar PV is expected to account for 21% of generation capacity (AEMO 2016). Queensland has the highest forecast growth over the next decade of all states in Australia, with residential growth remaining steady but expansion of 23% within the commercial sector (AEMO 2016). 2015 also saw the addition of the first commercial solar PV generation plants. Three plants were constructed in NSW with a combined capacity of 175MW. Similar installations are planned in Queensland with a goal of 125MW by 2020 (Australian Energy Regulator 2015).

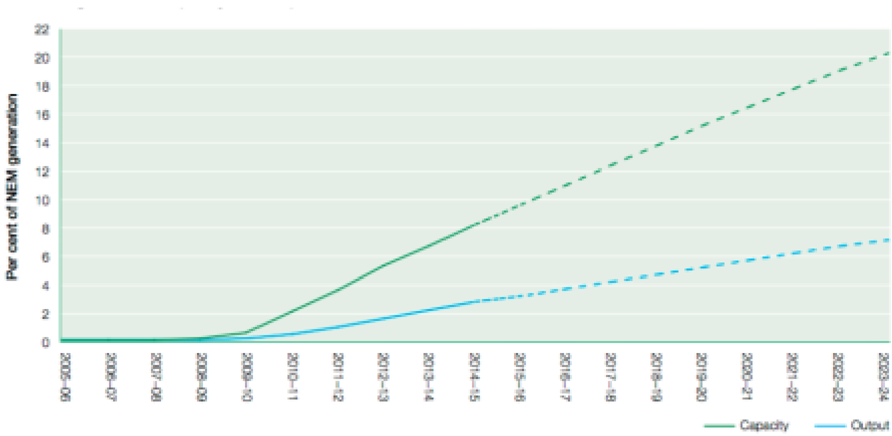

Figure 4: Percentage contribution of solar PV to national energy supply (Australian Energy Regulator 2015).

This market overview, though brief, illustrates that a complex set of factors are driving the ageing Australian energy market into a period of uncertainty and transition. Increasingly, renewable energies and in particular solar PV and wind are vital not only for environmental reasons, but also for financial efficiency and grid resilience. As the changes described here continue to intensify, large scale structural overhaul of electricity markets is increasingly plausible.

2.2 DISTRIBUTED SOLAR ENERGY NETWORKS: A FUTURE ENERGY PATH FOR AUSTRALIA

The current transitions in demand, supply and generation mix within the AEM leave the future of solar energy and the broader Australian energy market highly uncertain. Currently, uptake of solar PV is heavily reliant on Government driven subsidy and incentive schemes, but, as prices fall and new technologies emerge, the forces that drive solar adoption may change; especially within the growing strata marketplace.

Improving the competitiveness of solar against coal, gas and other fossil fuel generation techniques is largely dependent on how effectively solar is implemented. As Climate Works Australia (2014) points out, the right mix of strategies, innovation, policy and market instruments means that it is entirely possible to decarbonize energy supply in Australia by 2050, whilst still growing the economy.

There are two chief ways in which the proportion of solar PV within the NEM generation mix can be increased: large centralized power plants or distributed networks of small solar installations. Each of these methods is associated with an established 'management model', that underpins the relationship between energy suppliers, consumers and grid infrastructure. Large centralized solar PV plants subscribe to the current 'top-down' or 'unidirectional' management system that prevails within the fossil fuels energy sector, where energy flows from suppliers to consumers in one direction (see figure 5). The use of solar PV in a 'top-down' centralized framework requires extremely large capital investment and fails to recognize the unique benefits of solar, such as locational flexibility, enhanced energy security and improved market participation (Hansen & Lacy 2013).

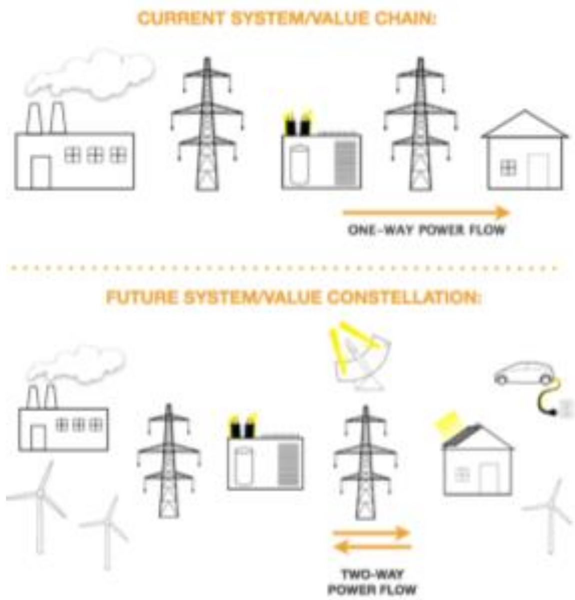

Figure 5: Centralized energy flows (top) compared to distributed generation energy flows (bottom) (Hansen & Lacy 2013).

Distributed generation describes a number of small on-site generation sources (such as a solar panel or wind turbine) working in concert to either meet local power demands or feed energy back into the wider grid architecture (Chowdrey & Tsen 2007). Distributed energy is decentralized, modular, flexible and adaptive and generally makes use of renewable energy sources. More so than just relocation of energy production, distributed generation represents a reorganization of energy markets that can increase individual participation, improve the efficiency and function of markets, and ultimately lead to advancement of energy democracy (Rifkin 2011). Energy Democracy means that all people have access to enough energy produced in a way that neither harms the environment, people or social fabrics. This means moving away from fossil fuels and socializing and democratizing the means of energy production, with a corresponding change in attitudes (Local Energy 2014).

Distributed energy enables ordinary consumers to become energy producers, buying and selling renewable energy production within local community markets, optimizing infrastructure to suit individual needs and using participatory decision making to manage energy use outside the top-down centralized power model (Rifkin 2011). Distributed generation brings with it several other technical benefits, including increased energy resilience (in response to both market price fluctuations and natural disasters that disrupt grid supply), cheaper unit price of energy because of economies of scale, enhanced flexibility of electrical network design and enhanced power quality and reliability (Chiradeja & Ramakumar 2004).

Centralized architecture and high-voltage power distribution has traditionally been a low cost and highly efficient method to distribute energy across a large network such as Queensland's, but these advantages quickly erode when a more complex generation profile that includes solar and/or other renewables is introduced into the network. Because of these changes, it has been identified that the prevailing 'top-down' structure is no longer the most effective option (Hancock 2011). This view is mirrored not just in Australia, but in foreign nations as well. China's planning authority for example, has recently revealed in its 12th 5-year-plan that of its 15GW solar target, 7GW is intended to be distributed generation designed to meet the needs of communities (Lewis 2011).

Distributed generation favors a much more collaborative framework where energy can flow freely between many suppliers and consumers, and makes maximum use of the inherent benefits of solar PV. Because of the shorter lead time and smaller unit size of installations, investment in Distributed Generation is preferred when growth in demand is low and energy market supply is high (as discussed in section 2.1) (Tongsopit 2008). This means that distributed solar is ideally suited to current market conditions, and could decrease average prices by up to 12% in 2030 and 65% in 2050, by helping to smooth volatility in the market through the distributed networks capability to respond to local supply-demand imbalances (McConnell et al 2013).

Despite the suitability of distributed generation for Australia's energy market, there are numerous barriers currently preventing its widespread utilization. Many of these are based in the fact that, under today's regulatory and pricing structures, multiple misalignments along economic, social and technical dimensions are emerging (Hansen & Lacy 2013). For example, the majority of pricing mechanisms do not fully reward the services and utility that customers who install distributed generation provide. Where this utility is recognized, through policy schemes such as the Renewable Energy Target (RET), the policies are often poorly designed and simply shift costs from one party to another, rather than utilizing the potential for economy wide economic and environmental improvement that distributed generation presents, such as its ability to display expensive sources of peaking generation (Center for International Economics, 2013).

Current solar business models do not incentivize deployment of distributed generation in a way that maximizes the operational benefits of the system. As such, many customers often evaluate distributed generation in a negative sense, associating it with high costs, complex system management and loss of revenue (Northern Alliance for Greenhouse Action 2016). As such, customers are generally only incentivized to install solar systems that maximize short term financial benefit. These issues are reflected in the current average size of installation in Queensland (4kw) compared to those in Germany (10kw) where greater value if placed on the benefits that distributed solar energy can provide and pricing and incentive schemes reflect this value (Bruce 2016). Many customers are also limited in their ability to effectively install distributed generation, because of issues such as availability of physical space, concerns over ownership and management in a multi-tenant dwelling, high upfront capital costs, limited understanding and conflicting information (Phillips 2012).

2.3 SOLAR PV AND STRATA

This section provides and overview of the strata market in Australia and describes the present difficulties in implementing solar PV systems in these buildings.

Strata title is a form of property law that was first pioneered in Australia and has since spread around the globe. Buildings that exist under strata title allow full ownership of private areas (such as individual apartments) and shared ownership of common areas, such as such as pools, foyers, lifts etc. Common areas are managed by an Owner's Corporation or Strata Management Company. Strata title can be applied to both commercial and residential buildings (Strata Community Australia 2016). As Wattblock's building assessments specifically target residential strata buildings, these are the focus of this report.

Strata title is a rapidly expanding sector of the Australian housing market. More than 270,000 strata schemes exist in Australia encompassing more than 2 million individual lots and housing more than 5 million Australian's (Strata Community Australia 2013). Strata title now accounts for more than 50% of all residential sales. Queensland in particular represents a large strata market sector, with more than 415,814 lots. Though projected growth of strata titled buildings is variable, most predict growth of 30-50% by 2030 (Strata Community Australia 2013).

Queensland strata buildings are some of the most suitable in Australia for installation distributed solar PV, for the reasons outlined below:

1. Queensland has some of the highest solar irradiance rates of Australia and the world (Bureau of Meteorology 2016).
2. 50% of strata lots (216,398) contain more than 50 apartments. This means higher than average common and apartment energy consumption per building or a higher than average 'energy consumption density'. This means larger than average solar installations are possible to meet energy consumption needs (Strata Community Australia 2013).

Despite the potential for distributed solar PV implementation in strata buildings, uptake has been less than that in detached housing (Roberts 2015). Where systems are installed, they are generally much smaller than roof space allows. Implementation and system size are principally limited by financial and governance issues. For example, it is difficult to resolve issues with ownership and management of the panels between Strata Managers, Owner's Corporation, owners and tenants (Phillips 2012). Furthermore, the Owners Corporation may have limited capital that can be used to invest in solar, or have difficulty in establishing sufficient voting support to install the system.

When installed, the size of solar is limited by the falling value of feed-in tariffs, which are now beneath 8c/kWh in Queensland. These low feed in tariffs provide poor financial incentive for strata to install a solar panel array of a size that will exceed that daytime usage in common areas (known as the common area load profile), even if roof space allows for a large system. Offsetting daytime common area energy usage results in substantial savings per kWh equal to the grid price, but outside the common area load profile, any electricity produced will be fed into the grid at a rate that delivers poor return on investment. Thus, it is most economically efficient to size the system to only meet common area needs, resulting in underutilization of solar PV.

In Queensland however, the common area load profile often represents a relatively small fraction of the total energy consumed in a strata building (Strata Community Australia 2013). Currently, solar systems are not installed to serve both common and residential load because of the aforementioned governance issues, and because of a lack of low cost technologies that allow for accurate metering, tracking of energy usage and billing.

Enabling the sale of electricity generated from solar panels to both common areas and residential apartments drastically increases the daytime energy consumption that can be powered by solar and hence increases the maximum system size whilst still avoiding grid feed in. In turn, this increases the quantity of grid electricity consumption that can be avoided, reducing emissions and potentially resulting in savings.

Digital Solar allows the sale of solar energy to both common and private residential areas, and hence has the potential to increase the maximum viable system size. Figure 6 summarizes the differences between standard and Digital Solar installations in strata.

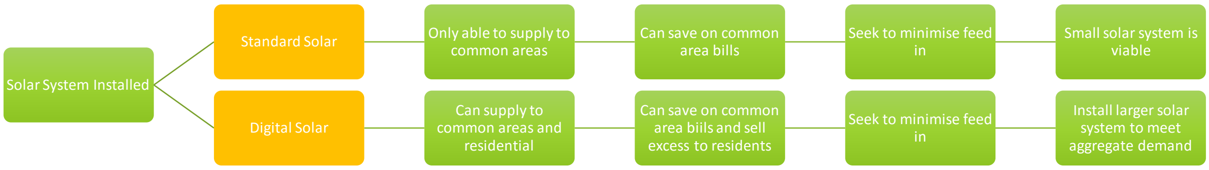

Figure 6: Key differences between digital and standard solar systems in strata.

2.4 DIGITAL SOLAR

Digital solar is a recently released technology that is becoming established in the Australian renewable marketplace. The technology is a union of advanced meters, cloud processing and bill creation software that works with existing solar PV technology. Key system components are presented in figure 3 below.

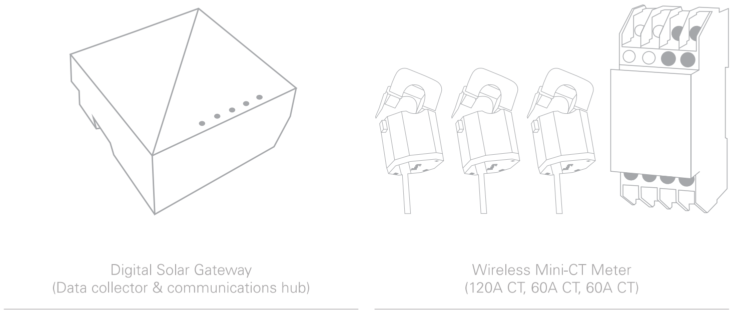

Figure 7: Digital Solar System Components (McGregor 2016).

Key system components are described below, based on information from McGregor 2016:

- Digital Solar Gateway: The key processing unit that collects meter data, aggregates this information and feeds this to the cloud platform. The gateway is also equipped to allow for building automation and smart metering. One gateway can collect data for up to 256 meters. Currently however, each gateway is coded to handle 3 meters.
- Wireless Mini-CT Meter: These components collect the primary usage information for both common and private residential areas. The meters take the form of a CT clamp and are capable of sending data wirelessly to the gateway for processing. Wireless meters have a range of up to 10 meters.
- Cloud Processing Platform: Responsible for performing data analytics and computation to track solar energy usage of common areas and individuals. This data is used to create solar consumption bills specific to each user.

In the case of strata buildings, Digital Solar's energy tracking capabilities and billing architecture allow solar electricity to offset common area usage and then on sell any excess generation to private apartments (McGregor 2016). This enables reduced energy usage and increased savings for all participants. By offsetting daytime common area usage, the Owners Corporation saves on grid consumption costs. Residents are also able to save by purchasing energy generated by the panels at a rate lower than they would pay for grid energy supply. For example, residents may be able to purchase solar generation at a rate of 20c/kwh instead of the grid price of 30c/kwh, thereby saving them 10c/kWh on electricity costs when the panels are generating.

Because of this, Digital Solar has the potential to address some of the structural misalignments that exist within the current renewable energy market. Today's operational and pricing structures (such as the feed-in-tariff), are still primarily designed to work in with the centralized methods of energy generation. As such, current renewable incentives are often poorly adapted to distributed generation systems (such as rooftop PV), causing inefficiency and friction in the marketplace, hindering adoption and thereby reducing the effectiveness of the technology at reducing carbon emissions (Hansen & Lacy 2016). To date, there has been limited research and discussion of how emerging renewable technologies and business models could improve market conditions and environmental outcomes in Australia.

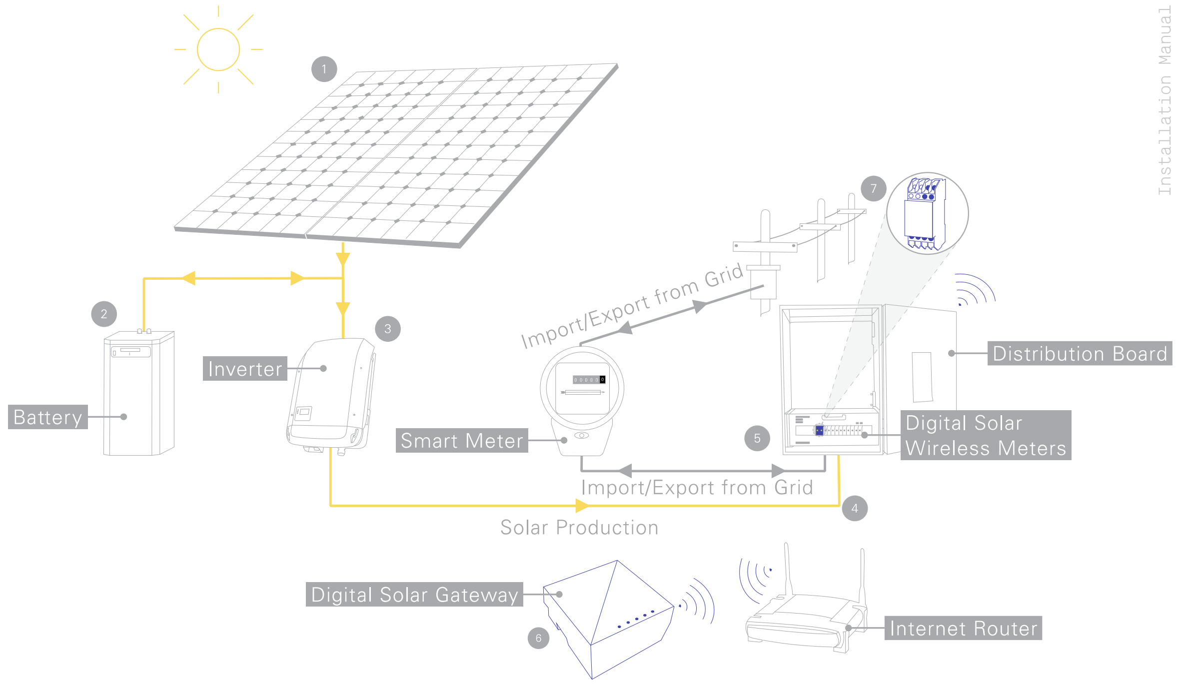

Figure 8: Digital Solar system operation (McGregor 2016).

2.5 DIGITAL SOLAR IN STRATA: COMPLEXITIES AND LEGAL STRUCTURE

Although Digital Solar is already utilized in detached landlord-tenant housing, its implementation in strata is not yet established. As such, a new legal and financial framework was required to be established for this project to integrate the system into complex strata management laws. This framework was developed by working closely with key project stakeholders and Wattblock management, and is by no means final.

In a legal sense, the use of Digital Solar in strata is constrained by the following factors:

1. The Owners Corporation cannot be an asset owner of the solar panels and cannot sell power to itself on the common meter.
2. Individual owners cannot be an asset owner of the solar panels and sell power to the individual apartments (but not offsetting own common area power).
3. Wattblock cannot be the asset owner of the solar panels and sell power to the Owners Corporation and apartments.

To resolve these issues, installation of Digital Solar on strata buildings will require the creation of a trust that is the initial investor and asset owner of the solar panels and digital solar system. The trust can be comprised of any owners or residents in the building willing to invest. Under this model, the Trust will act as a 'landlord', and sell power generated by the solar panels on to the Owners Corporation. The Owners Corporation purchases electricity sufficient for both common area needs and residential use at a rate negotiated between all parties. Energy purchased by the Owners Corporation that is not utilized to offset common area usage is 'donated' to the residents. Residents who use this energy pay for the costs of consumption through a Digital Solar levy, calculated based upon precise consumption data collected by the digital solar meters and monthly Digital Solar service fees. Figure 5 illustrates this process.

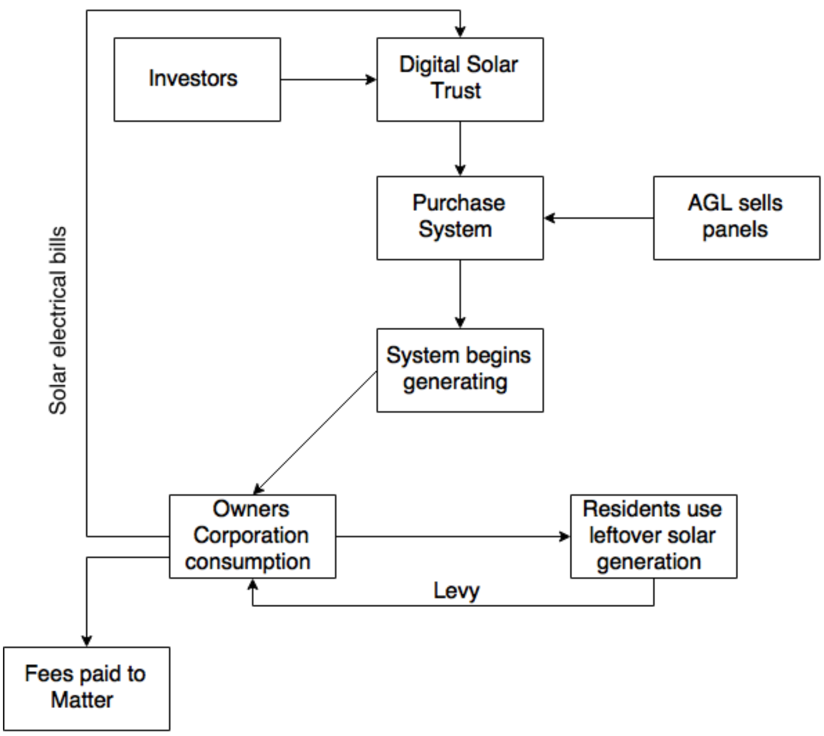

Figure 9: Legal framework created to enable Digital Solar operation in strata.

3.0 QUEENSLAND STRATA SAMPLE

The sample for this study is a collection of 10 buildings from Wattblock's Queensland database. These buildings were selected for inclusion based upon their varied layout, size, location and energy consumption characteristics. This variability means that even the relatively modest sample size can be considered to be representative of Wattblock's typical client base.

A summary of major characteristics for each building in the study is presented in table 3 below

Table 3: Key building characteristics for the 10 sites included in this study.

Building Name	Roof Area (m^2)	Total Floors	Total Apartments	Class
Building 1	1762	3	14	Low
Building 2	650	15	38	High
Building 3	100	4	22	Low
Building 4	450	10	57	High
Building 5	1200	5	27	Mid
Building 6	1443	6	61	Mid
Building 7	947	15	45	Low
Building 8	230	7	12	Mid
Building 9	900	21	57	Mid
Building 10	80	4	23	Low

The buildings studied were widely distributed throughout the major urban centers in Queensland. Figure 10 shows the spatial distribution of these buildings.

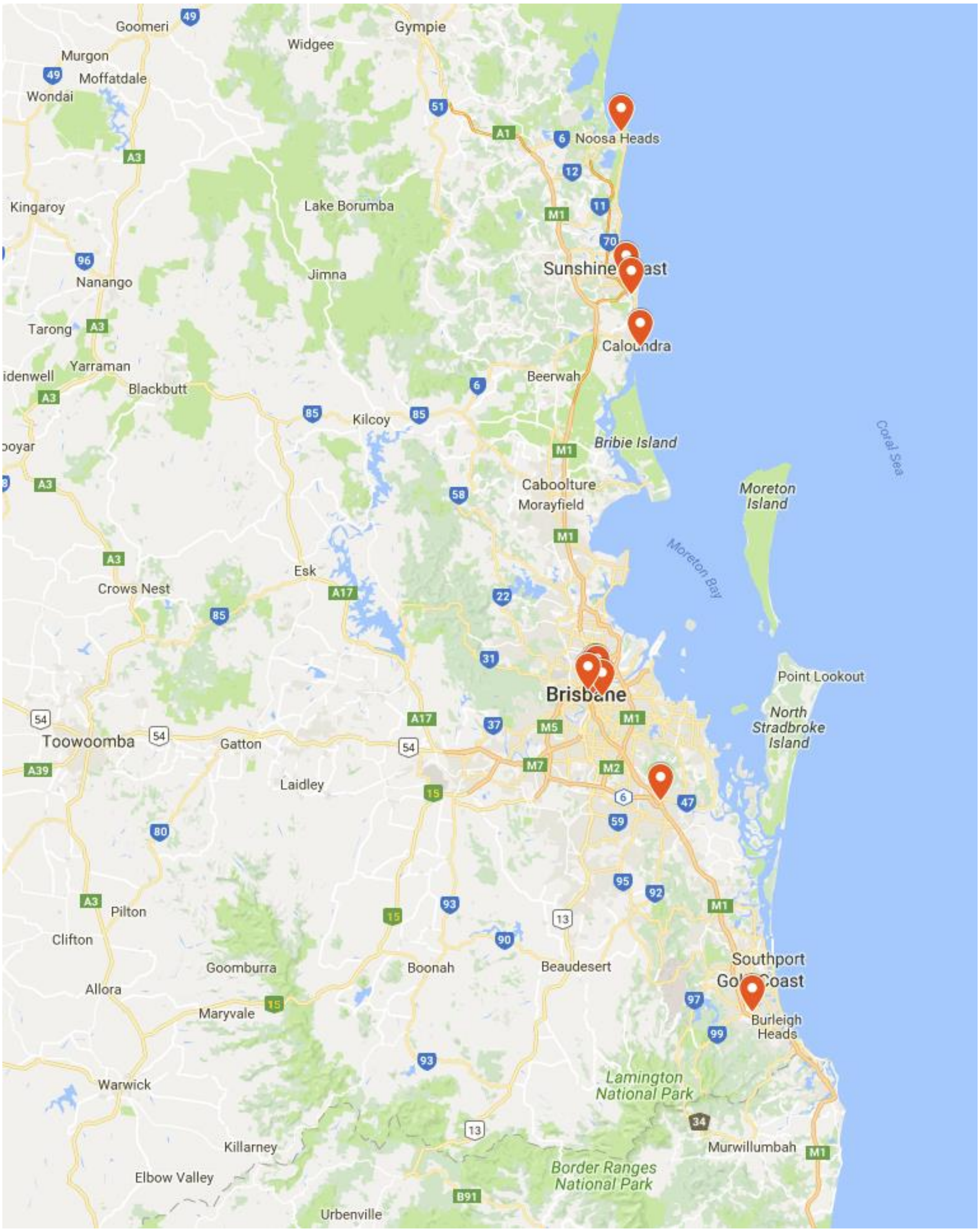

Figure 10: Location of buildings included in the study.

DIGITAL SOLAR FEASABILITY ANALYSIS

This section of the report explores the feasibility of Digital Solar in strata buildings across four separate criteria. These are:

1. The contribution of Digital Solar to an increase in the viable size of solar installed on a strata property
2. The environmental benefits and considerations of the technology
3. The economic and financial feasibility of the technology
4. Its contribution to the wider transition towards distributed energy systems

For each of these criteria, a description of key methodologies is included, results presented and key issues discussed.

4.0 PILLAR 1: SYSTEM SIZE INCREASE WITH DIGITAL SOLAR

Prior to evaluating the economic and environmental performance of Digital Solar, it was vital to establish whether or not financial incentives provided by the technology actually enabled the installation of larger solar systems.

4.1 METHODOLOGY:

Calculation of the potential system size increase was a multi-step process involving the use of existing Wattblock building data and solar spreadsheets coupled with information gathered from literature searches. The following sections outline and justify the step-by-step process undertaken. The initial investigation was broken into two 'tests' as indicated below.

4.1.2 TEST 1: CAN THE ROOF ACCOMMODATE A LARGER SOLAR SYSTEM?

Evaluation of potential system size increase requires computation of the 'rooftop solar potential' for each strata building in the study. This metric is an estimate of solar size based on utilizing 100% of available roof area. Where the rooftop solar potential exceeds the size of the standard solar installation proposed by Wattblock, the building is physically capable of accepting a larger system if effective incentives are established.

Rooftop solar potential is calculated as follows:

$$Potential\ Solar\ Size = Roof\ \ Area * 0.12$$

The data sourced for this calculation is presented in the table below.

Table 4: Data inputs for test 1.

Metric	Estimate	Notes	Source
Roof Area	Varies	-	Building site plans
Roof Solar Factor	0.12	Derived from average surface area of 250W solar panel	Wattblock Solar Spreadsheets

This calculation does not account for advanced shading data, rooftop ventilation, or other obstructions. In many cases, these factors would reduce the amount of useable roof space and hence diminish the potential solar size (Nguyen & Pearce 2012). Future studies should aim to incorporate these factors into a more comprehensive analysis of physical building characteristics. The rooftop solar potential findings in this study can be considered an optimistic estimate of best-case conditions.

4.1.3 TEST 2: WHAT IS THE POTENTIAL SIZE OF THE ROOFTOP SOLAR SYSTEM WHEN ACCOMPANIED BY DIGITAL SOLAR TECHNOLOGY?

Once the rooftop solar potential of a building is established, this data can be incorporated into existing Wattblock solar spreadsheets to estimate the potential system size with Digital Solar technology installed. Though the exact function of these spreadsheets is not discussed in this report, the following points indicate the changes that were made to existing templates to enable these calculations, or the steps utilized that deviated from Wattblock's standard solar estimate process. Table 5 presents the data that were used in these calculations and describes their origin.

1.

Common area and residential apartment yearly load profiles were individually estimated for each hour of the day, and then combined to estimate a 'Digital Solar service load' (i.e. the aggregate common and residential load that Digital Solar has the potential to offset). Larger aggregate load profile means that Digital Solar can offset more energy (and hence a larger system can be installed) whilst avoiding grid feed-in. Common area energy usage statistics were derived from billing data for each property. Residential energy usage was developed based on estimation using the formula below:

$$Assumed\ Apartment\ Energy\ Use\ (kWh)_{Yearly} = Daily\ Consumption\ (kWh) * Number\ Apartments * 365$$

Billing data and the aforementioned calculation give estimated common and residential yearly energy consumption, but do not break this down into a 'load profile', which describes the energy usage *patterns* over 24hours of the day. The assumed load profile for both common and residential areas takes the shape of figure 11. This profile was developed based upon consumption data presented in appendix A.

Calculating the energy use at any given hour for common or residential areas is as follows:

$$Yearly\ Load(kwh)_n = Total\ Energy\ * Usage_n$$

Where n is the hour

Thus, estimation of the 'Digital Solar Service Load' at any given hour is:

$$Digital\ Solar\ Load(kWh)_n = Common\ Area\ Load_n + (Apartment\ Load_n * Adoption\ Rate)$$

Where n is the hour

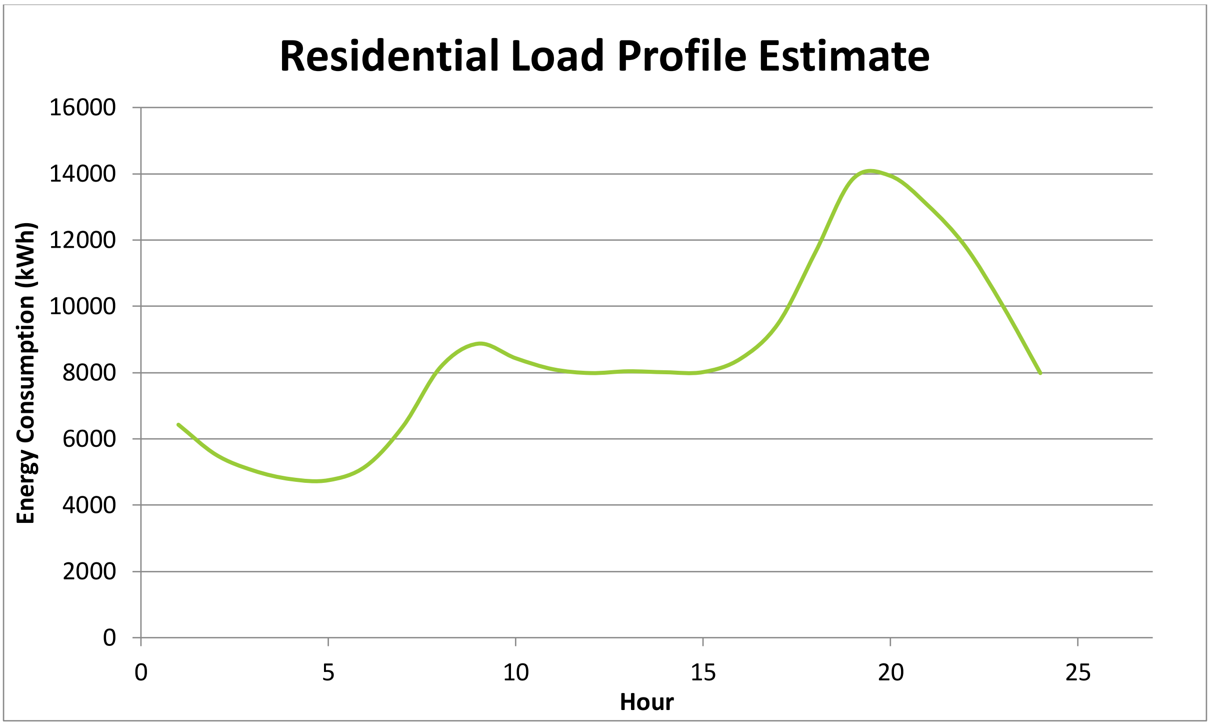

Figure 11: Assumed load profile developed for use in this study. Based upon preexisting data in Wattblock building energy usage spreadsheets.

2.

Digital Solar service load estimates were substituted into preexisting Wattblock solar calculation spreadsheets. These sheets calculate the scaled energy output of a given sized solar system hourly, by using the previously calculated load profile data and the output of a benchmark 100kw solar system located in Brisbane. This benchmark output data is derived from the PV Watts online solar estimation tool. Output is referred to as 'scaled' in this case because it is estimated based on the default 100kw system and calculated as follows:

$$Scaled\ Solar\ Output_n =\ 100kw\ benchmark\ output_n * System\ Size$$

Where n is the hour

Once the new Digital Solar service load is substituted into this spreadsheet, the desired output from solar panels can be adjusted to maximize the proportion of energy consumption that is offset by solar, whilst keeping feed-in rates at 10%. Because the energy output of solar is directly proportional to the size (in kw) of the system, this process allows indirect adjustment of the solar size. A ‘goal seek’ function was used to adjust desired energy output from solar such that the 10% feed in was realized, thus resulting in calculation of the optimal system size with Digital Solar installed.

Note: Maximum digital solar size is limited to 100kw, to remain eligible for STC generation certificates.

3.

Once calculation of the optimal digital solar system size was completed for all buildings in the sample, it was vital to establish with a degree of statistical certainty whether or not these changes were significant. A paired t-test was used to compare before and after sizes.

This was achieved using Excel’s T.TEST function. A one tailed test was performed, because only an increase in system size is the change of interest.

A paired T-test was utilized because system improvement represents a ‘before/after’ scenario where data are not necessarily independent from each other.

Table 5: Key data inputs for test 2.

Metric	Estimate	Notes	Source
Percentage solar production fed to grid	10%	Selected to match pre-existing Wattblock solar estimates to ensure consistency and fair comparison	Wattblock Solar Spreadsheets
Solar Output for a 100kw system in Brisbane, Australia	Hourly panel output in kWh for 365 days	Assumes a standard, fixed rack system with system losses of 15% and inverter efficiency of 96%	PV Watts Solar Calculator (National Renewable Energy Laboratory 2016)
Standard Solar Size	Varies		Wattblock solar datasheet
Roof Area Potential	Varies		Test 1 Results
Common Area Energy Use	Varies		Building Energy Billing Data
Common Area Load Profile	Varies		Billing Data and assumed load profile from Wattblock data spreadsheets
Residential Energy Use	Varies		See 'Apartment Energy Use' formula
Residential Load Profile	Varies	Load profile is an estimate based on average consumption patterns	Wattblock Data Sheets
Assumed Apartment Daily Consumption	14kWh		(Australia Bureau of Statistics 2012)
Number of Apartments	Varies		Building site plans
Adoption Rate of Digital Solar	100%	Adoption rate assumed because of legal framework requirements	-

4.2 RESULTS:

Preliminary investigation indicates that Digital Solar's incentives to supply solar energy for both common and residential areas is effective in increasing the size of the system installed. Average increase in the system size was 316%. Table 6 below summarizes the predicted size increase for each building studied. Figure 12 summarizes this relationship graphically.

Building 6 recorded the absolute largest system size, at 90kw, but the greatest size increase occurred at Building 7, where the Digital Solar system was 691% larger. The smallest increase in system size was 102%, and occurred at Building 10, where roof space only allowed for the installation of a 9.6kW system.

Table 6: Observed improvement in solar system size with implementation of Digital Solar.

Location	Standard Solar Size (kW)	Digital Solar Size (kW)	Improvement (%)
Building 1	8	22.78	185%
Building 2	11	51.03	364%
Building 3	2.8	15	436%
Building 4	13.27	54	307%
Building 5	30	90	200%
Building 6	24.28	52.75	117%
Building 7	6.58	52.04	691%
Building 8	4	17.07	327%
Building 9	14	75	436%
Building 10	4.75	9.6	102%

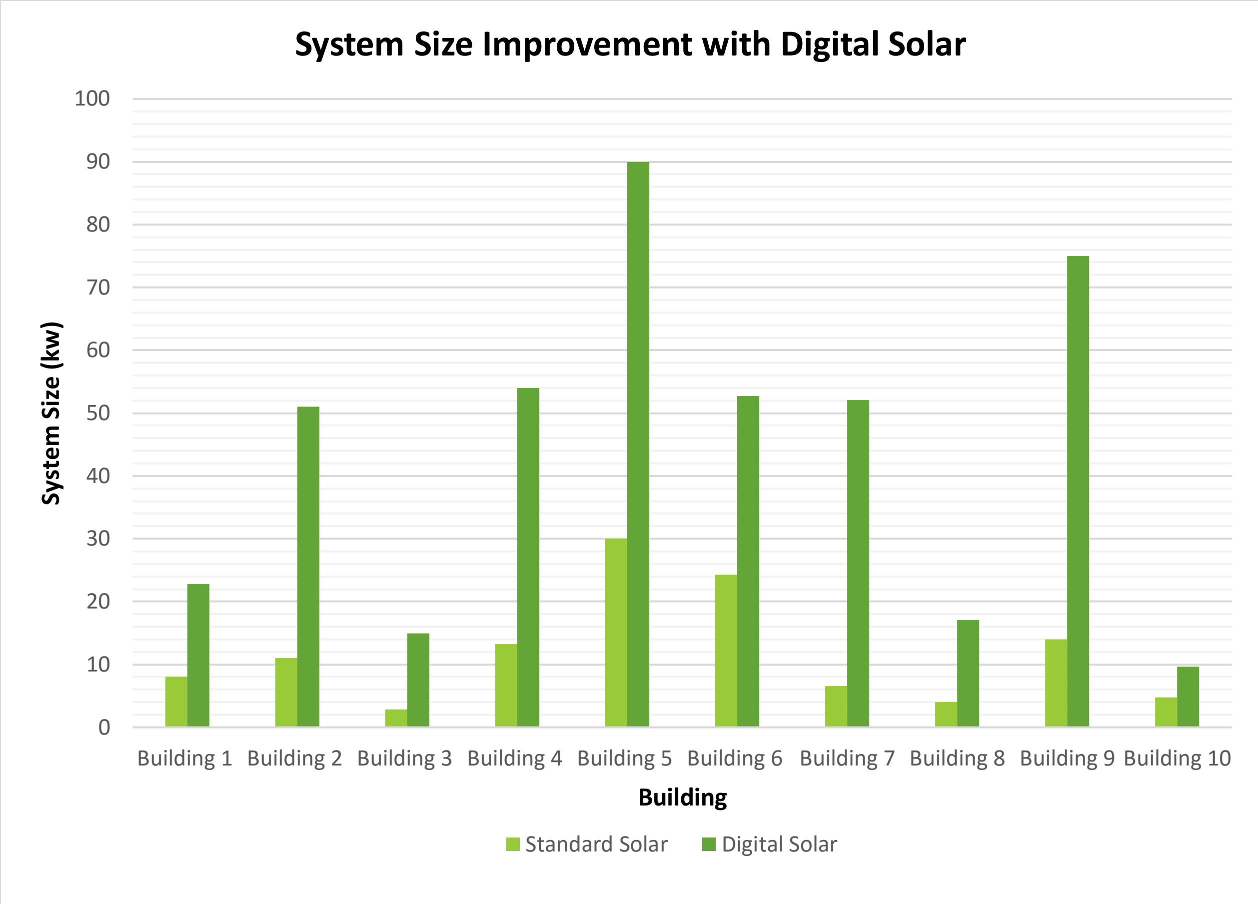

Figure 12: System size comparison between standard and Digital Solar installations.

Paired T-Test results return a p-value of 0.000384, indicating that there is a statistically significant increase in system size at a 99% level of confidence.

Digital Solar also significantly increased the rooftop solar potential realized (i.e. it enabled a larger proportion of the roof area to be used for solar production). Digital Solar realized 47% of roof space, compared to 13% for standard solar (see figure 13). For several buildings such as Building 10, Digital Solar enabled 100% of rooftop production potential to be realized.

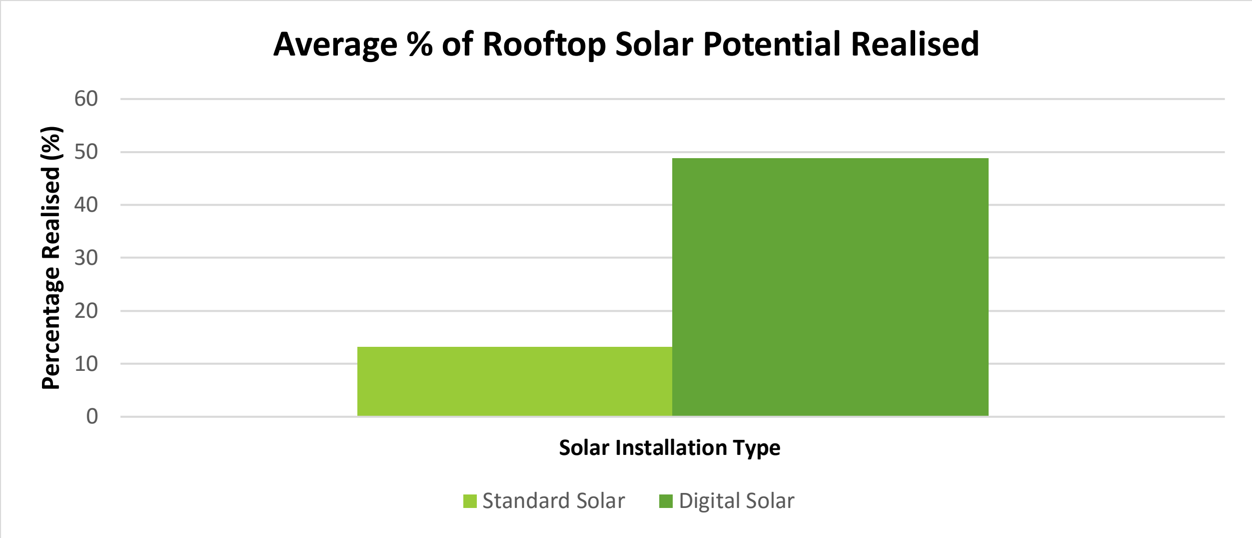

Figure 13: Percentage of solar rooftop production area utilised.

4.3 DISCUSSION:

As the results have clearly established, Digital Solar can drastically increase the system size that can be installed whilst avoiding an increase in grid feed in rates. This, in turn, allows potential for larger solar systems to be installed on strata buildings throughout Queensland. This discussion will explore the key factors that drive system size increases and discuss the potential ramifications of larger and more numerous rooftop solar installations in Queensland.

Table 7 describes the correlation between system size increase and several different building characteristics. Numbers closer to +1 or -1 indicate stronger correlation between variables. As the table indicates, many of the characteristics demonstrate a relatively weak association with system size increase.

Table 7: Strength of association between system size increase and several building characteristics.

Associated Variables	Strength of Relationship
Difference in Common and Residential Consumption/System Size Improvement	0.689
Roof Area per Unit/System Size Improvement	-0.303
Number of Apartments/System Size Improvement	0.282
Roof Area (m^2)/System Size Improvement	-0.165

The strongest association occurs between system size increase and the difference in common and residential energy consumption. A correlation coefficient of 0.689 suggests a reasonably strong positive association between the two variables. This suggests that, where the difference between the common area consumption and residential consumption is greatest, the greatest in improvement is system size with digital solar will also occur. This relationship is expressed in figure 14, which indicates a clear positive increase in system size as the difference in consumption between the two areas increases.

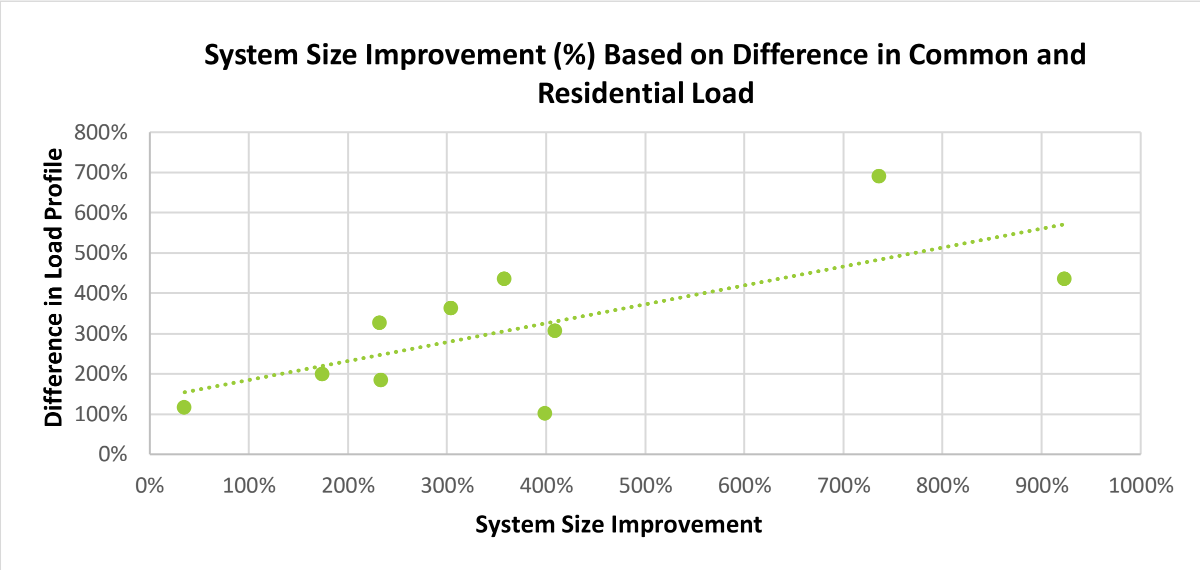

Figure 14: Association between system size improvement and difference in load profiles.

A large difference between common and residential consumption means that installation of Digital Solar (and hence the ability to sell solar energy to both areas) results in a meaningful increase in the total electricity consumption that solar panels can offset, allowing a larger system to be installed without increasing the feed-in rate past 10%. This relationship also goes some way to explaining why system size improvement is only loosely correlated with factors such as number of apartments. Even in a building with many apartments (and hence large residential consumption), the increase in total load able to be offset by including residential apartments may only be minimal relative to that which can be offset with a standard solar installation.

To aid communication of this complex relationship, a visualization tool was developed for inclusion in any customer facing reports (see figure 15). The graph shows the theoretical maximum roof area solar production (orange), common area load profile and energy consumption (red), and residential load profile and energy consumption (blue). As the graph indicates, the common area load profile allows realization of only a small portion of the potential rooftop production. The overlap between the solar production and the residential load is the benefit accrued when digital solar is installed. In the example provided, this area is large and indicates a large difference between common and residential energy consumption. Thus, Digital Solar is likely to lead to substantial increases in solar system size at this property.

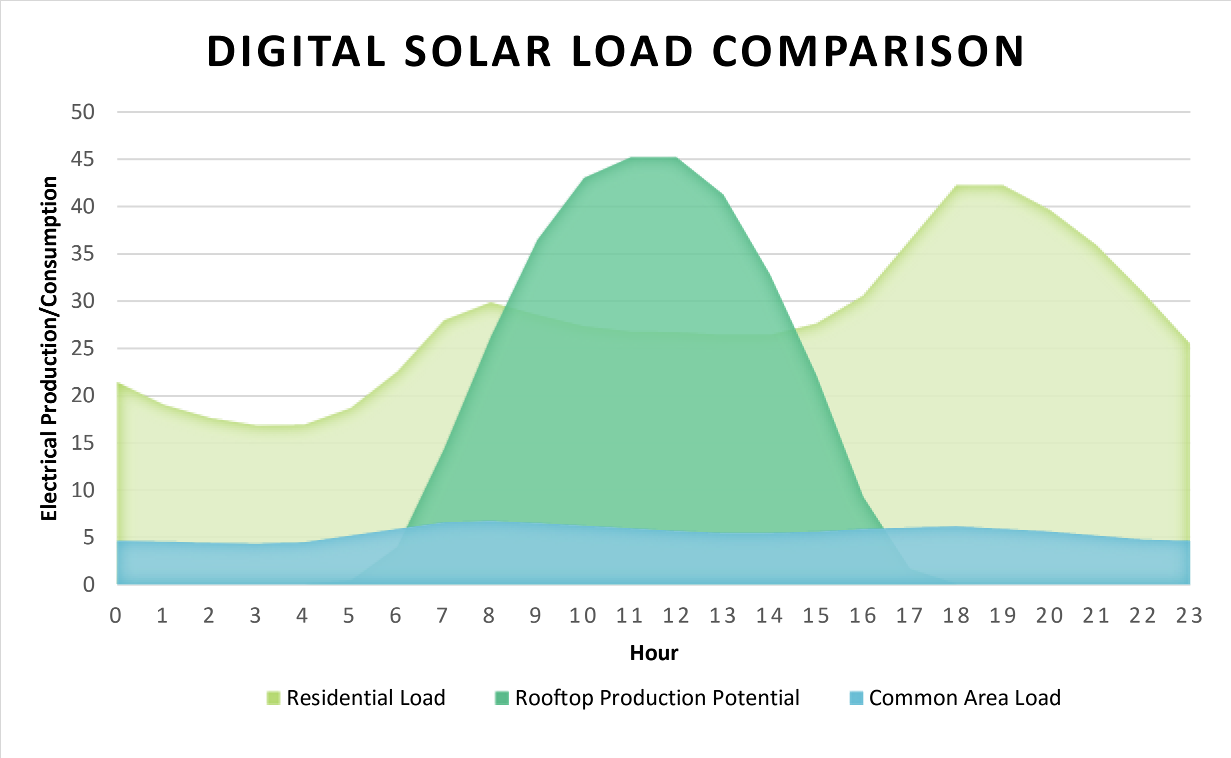

Figure 15: Digital Solar Potential visualization tool for inclusion in customer facing reports.

The critical association between residential area load, common area load and system size increase has important implications for buildings assessments and inclusion of the technology in Wattblock's reports. When assessing a strata building for Digital Solar, it will be vital to acquire accurate assessments of common and residential energy consumption. Whilst common area load data is easily sourced from billing history, accurate estimation of residential consumption (in kWh) and when that consumption occurs (the load profile) is much more difficult to gather, often requiring special agreements between strata managers, energy companies and assessors (Clarke 2016). Energy usage for individual apartments may be able to be gathered by conducting reads on each apartment meter in the building, but the interval data required to construct a load profile specific to each building is often closely guarded by energy companies (Clarke 2016). This issue does not exist where a 'bulk billing' agreement is in place (i.e. 1 bill is submitted to the Owners Corporation and then divided amongst apartments). Adoption of bulk billing in strata has been minimal thus far, though Queensland does have a slightly higher proportion compared to other states. These barriers may constrain the adoption of Digital Solar throughout the marketplace. In particular, the delays and complexities involved in securing necessary residential load profile information may impede the integration of this technology into Wattblock's reporting service, which relies on rapid and quickly scalable advice.

It is clear that Digital Solar has the potential to drive the adoption of larger solar panels on strata buildings by enabling the sale of solar energy to both common and residential areas. However, increasing solar adoption could have several impacts on the grid and energy market as a whole.

First, increased solar adoption in dense urban areas can significantly alter the load profile of the grid and the stability of electricity supply. As solar adoption increases, an increasing proportion of daytime electricity consumption can be satisfied with solar PV production, forcing power stations to ramp down their production. As figure 16 indicates, greater solar adoption increases the gradient of the curve from peak solar production to peak grid demand in the evening. To meet this sharp increase in demand, power stations need to be able to bring large amounts of generation capacity online in a short period of time. This demand can be satisfied either by using rapid 'peaking' generators or by coordinating a mix of different generation types to come online in unison (Denholm 2016). Either option is significantly more expressive per unit energy produced than more stable 'baseload' generators. As solar adoption increases and Queensland demand peaks grow more intense (as outlined in section 2.1), it is a strong likelihood that electricity prices may increase to compensate (Australian Energy Market Commission 2016).

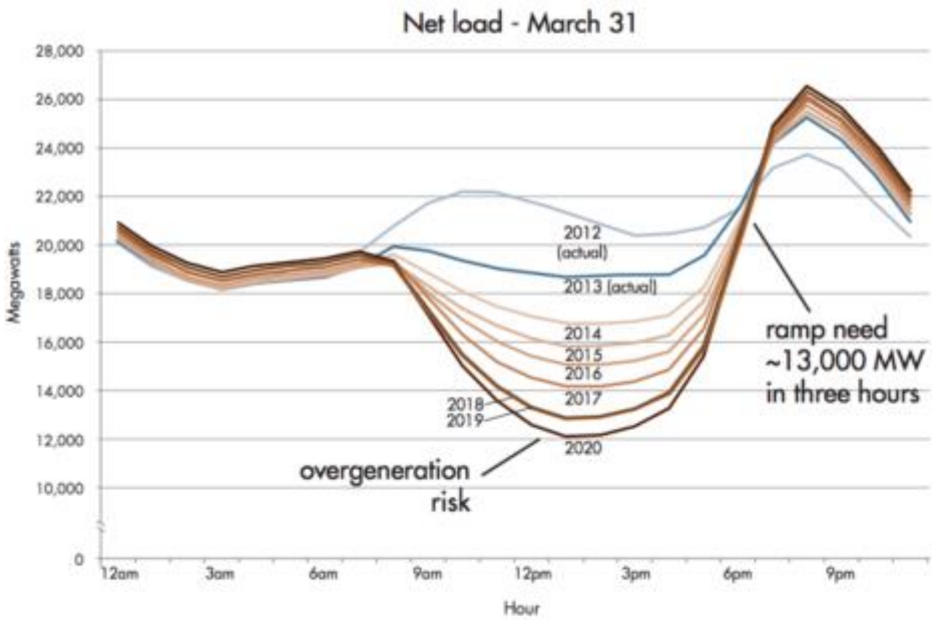

Figure 16: The 'Duck Chart', which illustrates the alteration to the grid profile that increasing solar adoption can cause (Denholm 2016).

Second, increased solar adoption may exacerbate energy market inequalities. As the demand for grid supplied electricity falls, generation plants can be decommissioned but essential grid infrastructure and transmission networks must remain and be maintained. This is because the infrastructure is still required for network reliability and distribution of baseload. Even if the distributed power networks discussed in section 2.2 were to manifest earlier than expected, distribution networks would be required to effectively share and direct electricity produced from a variety of locations to the users who need it most (Wood & Blowers 2015). Consumers typically support infrastructure upgrades through rates paid on every kWh consumed. Thus, consumers that install large solar systems through a technology such as Digital Solar have the potential to disproportionately shift the cost of grid maintenance and infrastructure upgrades to those who do not or cannot install solar.

In the case of an adopted 'smart grid' system (widely posited as the key technical factor in fostering truly distributed power networks), the investment costs to develop this network – though beneficial in the long term – could temporarily increase the price pressure of consumers who remain largely dependent on grid electricity (Rifkin 2011). Those who remain with centralized power may also experience a degree of isolation as solar users transition to distributed networks rather than centralized grid based generation.

However, price increases and inequality with increasing solar adoption are by no means certain. The way in which the NEM operates means that solar PV's downward pressure on total demand makes it likely that each bidding interval will finish at a lowed bidding price (known as the merit order effect), thereby reducing the amount paid in the wholesale market (McConnell et al 2013). If these savings are passed on to consumers, this has the potential to at least partially offset grid maintenance costs.

4.3.1 PILLAR 1 REVIEW: KEY FINDINGS

1. Digital Solar can potentially lead to a significant increase in the installed size of solar in strata by allowing the sale of energy to both common and residential areas.
2. The difference between common area energy usage and residential energy usage is strongly associated with the increase in solar size achieved by Digital Solar.
3. Installation of Digital Solar will require accurate load profile data that is difficult and/or time consuming to acquire.
4. Increasingly large solar installations could have a range of negative impacts on the energy market including increased electricity rates and difficult in meeting demand peaks.

5.0 PILLAR 2 ENVIRONMENTAL ANALYSIS:

Environmental analysis comprises three different metrics as following:

1. Lifetime emissions abatement
2. Energy Payback Time
3. Cost of Abatement

5.1 METHODOLOGY:

5.1.1 LIFETIME EMISSIONS ABATEMENT:

The key environmental benefit of solar PV is that the energy it generates reduces grid consumption, thereby achieving a reduction in greenhouse gas emissions. Quantifying the emissions abatement of Digital Solar is vital step to evaluate its contribution to wider emissions reduction goals and enable comparison with other energy efficient technologies.

Lifetime abatement was calculated based upon avoided electricity consumption and QLD state emissions factors. This calculation accounts for the degradation of PV panels over their estimated 25-year lifetime. Table 8 presents the key factors used to calculate emissions abatement.

Table 8: Key data inputs for calculation of lifetime emissions abatement.

Metric	Assumed Figure	Source
Avoided electricity consumption	Varies eg. 17000kwh	Wattblock Data Sheets and National Renewable Energy Laboratory (2016)
Queensland Emissions Factor	0.79kg CO_2e/kWh	Department of Environment and Energy (2016)
Annual Panel Degradation	0.05%	Jordan & Kurtz 2011
Assumed Panel Lifetime	25 years	Jordan & Kurtz 2011

Annual avoided electricity consumption is calculated based upon the assumption that solar energy offsets the grid consumption of common and residential areas during daylight hours. For example, the Digital Solar installation at Building 9 produces 101,569kWh over the course of year 1, so it is assumed that an equal quantity of grid based energy is not generated.

Calculating lifetime abatement is done as follows:

$$Abatement(tCO_2e)_{Lifetime} = \sum_{i=n}^{25} Abatement_i$$

This calculation involves summation of the abatement secured by the solar panels at each individual year over the 25 year lifetime, which is calculated as:

$$Abatement(tCO_2e)_n = ((Solar\ Production(kWh)_{n0} * (1 - (Panel\ Degradation * n\ ) * Emissions\ Factor)/1000$$

Where n is the year.

5.1.2 ENERGY PAYBACK TIME (EPBT):

Energy payback time describes how long it takes the Digital Solar system to recover the energy involved in its production. The energy that is utilized in manufacture of the panels is referred to as embodied energy. EPBT gives us a complete evaluation of the lifetime environmental benefits, and allows for true environmental impact to be evaluated and compared fairly between a range of different technologies.

EPBT is calculated as:

$$EPBT = \frac{Embodied\ Energy}{Energy\ Production(kwh)_{n0}}$$

Where n is the year

Embodied energy (the key metric in this calculation) is usually determined through a detailed life cycle assessment (LCA) for a specific project under a set of tightly controlled conditions. A full LCA lies beyond the scope of this project, and so several different estimated inputs were used, derived from industry and research data. These are presented in table 9.

Table 9: Key data inputs for calculation of energy payback time.

Metric	Assumed Figure	Notes	Source
Number of Solar Panels	Varies	$\#Panels = \frac{Solar\ Size}{0.25}$ Assumed output is 250W per panel.	AGL (2016)
Surface Area of each panel	1.5872m^2 per panel	Assessment based on multi-crystalline panels	Peng et al (2013)
Estimated Energy Input per m^2	749.72kwh/m^2	Low estimate for embodied energy based on literature research. Figure accounts for energy used to produce panel, aluminum stands and inverter.	Peng et al (2013)
Digital Solar Correction Factor	2%	Used to account for the additional hardware in the Digital Solar system.	-

Using the figures in table 9, the embodied energy of each system can be calculated as follows:

$$Embodied\ Energy\ (kWh) = (Number\ Panels * Panel\ Surface\ Area * Energy\ Input/m^2) * (1 + Digital\ Solar\ Corection\ Factor)$$

5.1.3 COST OF ABATEMENT:

The cost of emissions abatement is an important tool for quantifying the relative affordability of a project that reduces emissions. Comparing the costs of abatement for different projects is a valuable tool that can be utilized to invest efficiently and achieve greatest emissions reduction. It is important to distinguish that the cost of abatement calculated in this study is the *private* cost, which means that it only account for costs accrued by the Digital Solar investors. This differs from the abatement cost curves that are constructed by researchers and policy makers, which account for the true *social* cost of each abatement technology (by account for things such as subsidies and tariffs). Calculating the true social cost is a labor and data intensive process and hence lies beyond the scope of this study. However, it is recommended that future work calculates the social cost of Digital Solar, as this is a key metric for evaluating the ability of the technology to scale and help meet emissions targets.

Cost of Abatement was calculated as follows:

$$Cost\ of\ Abatement\ \left(\frac{\$}{tco2e}\right) = \frac{-NPV}{Lifetime\ Emissions\ Abatement\ (tCO_2e)}$$

*For this calculation, NPV is set to negative because a positive NPV indicates a negative total cost. Where project NPV is negative, a positive cost of abatement will be returned.

The key metrics involved in this calculation are presented in table 10.

Table 10: Key data inputs for calculation of Cost of Abatement.

Metric	Assumed Figure	Notes	Source
Discount Rate	9.5%	Annual interest rate on a Macquarie bank solar loan. Figure is correct as at November 2016	Wattblock Data Sheets
Solar Panel Lifetime	25	Average solar panel lifetime	Jordan & Kurtz 2011

5.2 RESULTS:

As figure 17 illustrates, Digital Solar installations delivered substantially larger emissions reductions, owing to an increase in the size of the solar system. On average, Digital Solar secured 288% greater emissions abatement than a standard solar installation. Digital solar installations secured abatement of 1068 tCO_2e compared to 275.21 tCO_2e. Greatest abatement was achieved at Building 5, which resulted in the abatement of 2974.3 tCO_2e over its lifetime.

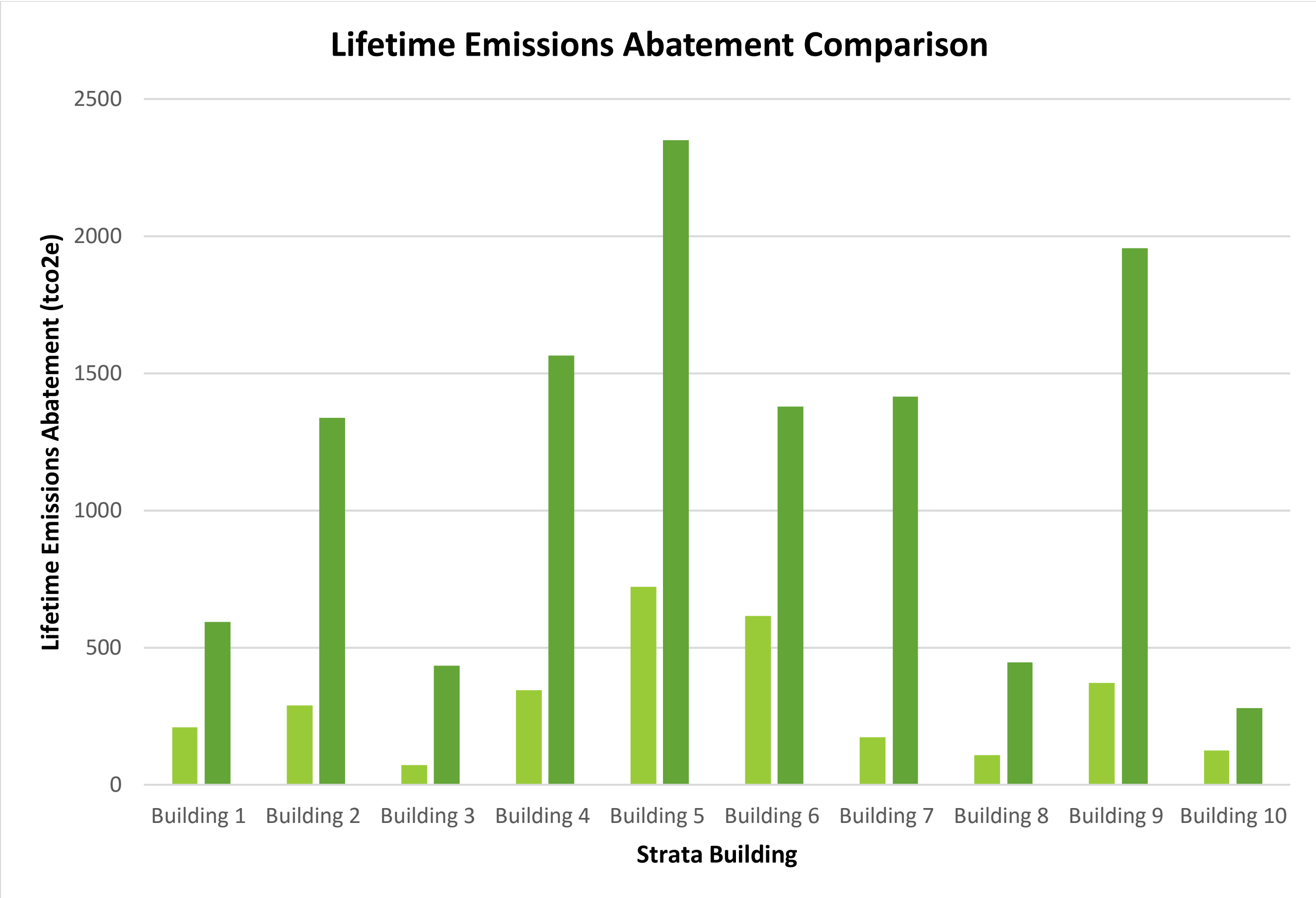

Figure 17: Comparison of lifetime emissions abatement between Digital and Standard solar installations.

Energy payback time exhibited only marginal variation between standard and Digital Solar systems, as indicated in figure 18. Average energy payback period for standard solar was 3.58years, compared to 3.47years for Digital Solar. This represents an average improvement in energy payback time of just 3.03%. As the graph below indicates, the greatest improvement in energy payback time occurred at Building 10, with a 10.75% faster payback compared to a standard solar system. In some cases, the additional resources required for digital solar were not offset by additional energy production, resulting in a marginally longer energy payback period. This occurred at Building 8, where a 3.58% longer payback period was observed.

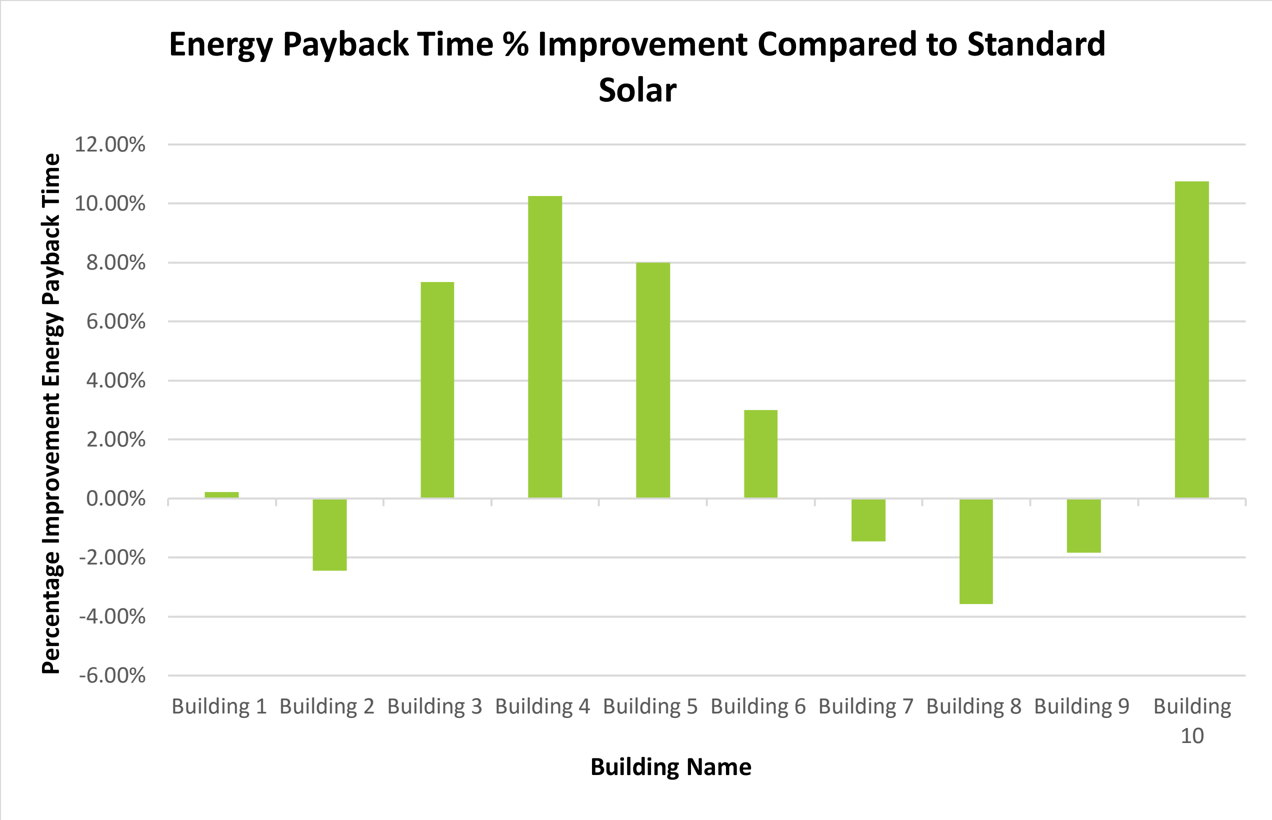

Figure 18: Energy payback time variation with Digital Solar installed.

Average private cost of abatement was \$3.98/ tCO_2e, indicating that Digital Solar emissions reduction are achieved at slight net cost to the trust investors. However, 60% of abatement costs were negative, indicating that Digital Solar emissions reduction was achieved at net financial benefit to the trust. The abatement cost for each property is indicated in figure 19.

The major outlier for this data set is the abatement cost for Building 10, which was \$137/tCO_2e. This high abatement cost was due to the relatively minor increase in emission abatement with Digital Solar, coupled with a high initial setup cost for this property.

Though the social cost is not included in this study, tentative conclusions based on private abatement cost and research suggest that the abatement cost of digital solar will not vary significantly from that of standard solar, which is estimated to have a social cost of \$170/tCO_2e (Department of Energy and Environment 2016)

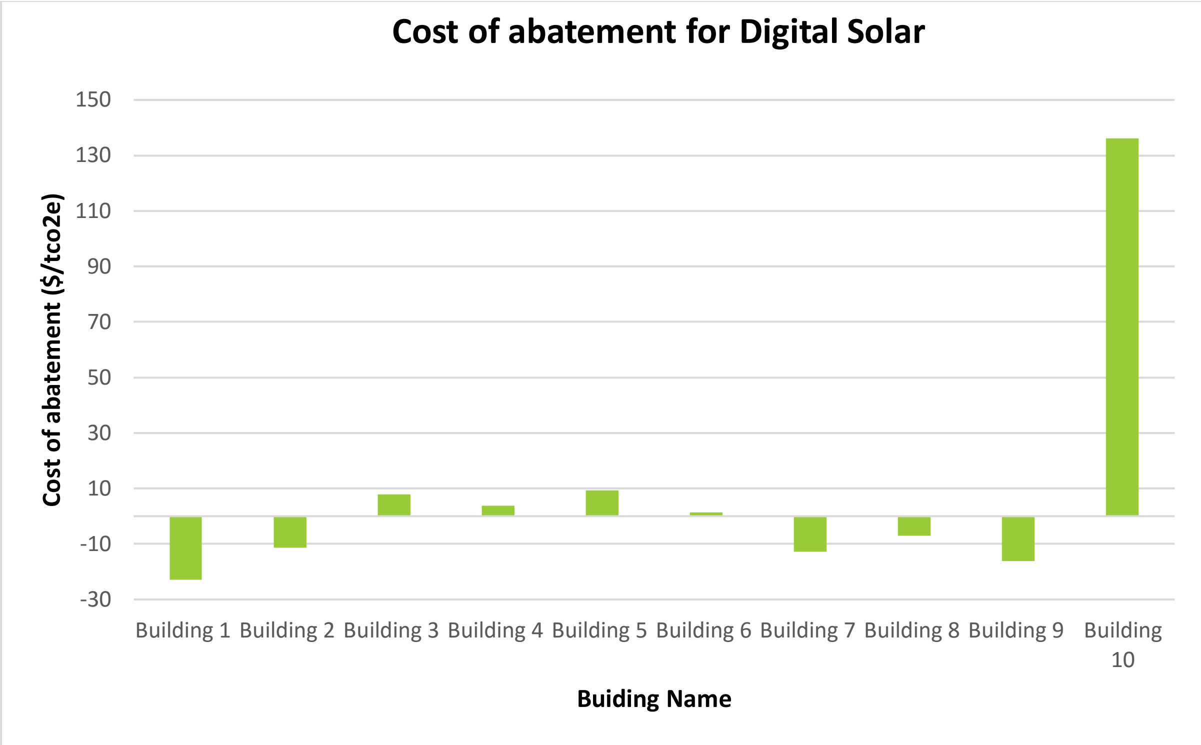

Figure 19: Cost of abatement for Digital Solar at each study site.

5.3 DISCUSSION:

As the results indicate, Digital Solar has the potential to drastically increase the emissions reduction potential of solar PV in Queensland's strata buildings. This is largely due to its ability to allow for the installation of a larger solar system and because the Digital Solar system itself requires negligible additional physical inputs (which would otherwise increase embodied energy).

Given the average increase in abatement of 288%, application of Digital Solar drastically increases the contribution that rooftop solar PV in strata can make to state and national emissions targets, such as the 26-28% reduction in emissions by 2030 proposed by the Federal Government (Department of Environment and Energy 2015). Achieving this would require a reduction in emissions of 171million tCO_2e by 2030. By 2030, the average abatement secured by the Digital Solar systems in this study is equal to 698.22tCO_2e. If this is extrapolated across the strata buildings in Queensland, this represents of emissions reduction by 2030 of 29$MtCO_2e$; a significant contribution to federal emission targets.

Though Queensland does not have a specific emissions reduction target, it does have in place a policy to reach 50% renewable energy generation by 2030 and 3000mW of solar PV output by 2020 (Department of Energy and Water Supply 2016). Given that most existing solar installations are approximately 3-4.5kw, Digital Solar can make significant contribution to these targets because it encourages the adoption of larger systems. For the 10 buildings in this study, Digital Solar secured an additional 0.3mW of solar power. If the average system size increase observed in this study were scaled across the 42,000 strata titles that exist in Queensland, additional solar production of 1806mW would be achieved. Given that Queensland already has approximately 1500MW of solar generation capacity installed, the widespread adoption of Digital Solar alone could potentially meet the 2020 goal of 3000mW generation capacity (Department of Energy and Water Supply 2016). Though these figure are only estimates, they do illustrate that widespread adoption of Digital Solar has the potential to make significant progress towards emissions and energy targets in Australia.

Digital Solar is an environmentally preferable way to achieve large solar installations when compared to centralized solar generation plants. This is vital finding, given that the Queensland Government is aiming to install 150MW of centralized solar by 2030 (Department of Energy and Water Supply 2016). Because Digital Solar can utilizes unused rooftop space, it avoids many of the negative impacts of centralized generation as described below.

Centralized generation plants can have wide range of environmental impacts, generally relating to their requirements for large areas of land. Centralized solar can cause the displacement of plant and animal species, loss of habitat and, in some cases, land clearing (Turney 2011). Depending on the scope considered, centralized installations can also have higher embodied energy, because they require to upgrade of construction of new energy networks and grid infrastructure. Centralized solar can also have impacts on cultural heritage values, by displacing and/or distributing artifacts or sacred sites (Turney 2011).

Because of these potential impacts, centralized solar projects have garnered significant criticism across the globe. In the Southwestern desert regions of the United States for example, recent solar developments have generated controversy regarding their disruption of native wildlife and habitat regions, requiring large offset and mitigation activities to be included in their Environmental Impact Assessments (Hernandez et al 2014). In densely forested regions, the environmental impact of solar farms can be almost as significant as those involved in the construction of a conventional coal fire power station (Hernandez et al 2014). In Queensland, it is highly unlikely that any solar developments will be located on densely forested lands. Assessment of the development proposals for large solar farms reveals that most are intended to be located on disused farmland that has already been cleared (Origin Energy 2016). However, future population pressure and increasingly stringent environmental regulation may force solar developments onto increasingly marginalized lands. In future, more comprehensive environmental studies should investigate the differences in environmental impact between centralized and distributed solar PV in a Queensland context more thoroughly.

Results indicate that energy payback time did not vary significantly between standard solar and Digital Solar systems. This result was expected, given that the Digital Solar system requires minimal additional material inputs (because of its entirely wireless transmission) and works with standard solar panels. From an LCA perspective, Digital Solar is unlikely to have impact on the environmental values on site, as it's installation and operation does not impact soil, water or local air quality. In most cases, small design adjustments also limit the potential impacts on site amenity.

Though Digital Solar itself has little direct impact on local environmental quality, it does encourage the adoption of larger solar PV systems, which could affect environmental values by increasing resource raw resource consumption. Studies indicate that the production and manufacture of solar PV is an energy intensive process that can lead to significant emissions depending on the local grid energy mix at the place of manufacture (Kannan et al 2013). The production process of both mono and poly crystalline panels requires several rare earth inputs as Tellurium, Indium and Germanium, some toxic inputs, as well as large inputs of aluminum, silica and zinc. Aluminum production in particular which is used in the production of solar rack mounts for strata rooftops), is a highly energy and resource intensive process, requiring large water inputs and the use of caustic agents (Tsoutsos et al 2005). Furthermore, the perfluorocarbons released during the aluminum smelting process are estimated to have a global warming potential 9200 times greater than that of carbon dioxide (Kannan et al 2013).

End of life decommissioning of solar PV panels also has several deleterious impacts, regardless of whether they are sent to landfill or recycled. Where panels are sent to regular landfill sites, there is a risk that cadmium can leach into the soil and toxic fumes can be emitted during fire events (Kannan et al 2013). Panel recycling meanwhile, is an energy intensive process that requires investment in specialist infrastructure and development of specific waste management policies. Recycling energy inputs are negligible compared to those utilized in the production process however, and it has been demonstrated that recycling 1 ton of silicon-based PV modules saves up to 1.2 tons of CO_2 equivalent compared to when manufactured from raw materials (Kang et al 2015). Most lifecycle assessments indicte that the recycling of solar panels results in a net environmental benefit, but requires careful management and procedure to optimize these potential gains. Australia currently has no policy to manage the end of life decommissioning, disposal and recycling of solar panels (Kang et al 2015). As Digital Solar has the potential to increase the size and rate of solar PV installation, it is highly recommended that policy makers look begin drafting management plans and that solar PV retailers are aware of how to best manage PV waste.

The abatement cost analysis included in this paper indicates that in most cases the abatement secured by Digital Solar is achieved at minimal or negative cost to investors. As such, Digital Solar is likely to be a palatable option for strata managers and Owners Corporations to enact but, as with normal solar PV installations, it is likely to remain a 'late stage' project that is installed only after the lowest hanging fruit options (such as LED lighting) are enacted. This is because efficiency and lighting projects are able to deliver large emissions reductions relative to investment and result in fast payback of initial invest. In some of the buildings Wattblock has prepared lighting proposals for, payback period for lighting has been less than a year.

PILLAR 2 REVIEW: KEY FINDINGS

1. Digital solar, by enabling the installation of larger solar systems can result in significant emissions abatement.
2. Energy Payback period did not vary significantly between standard and Digital Solar installations.
3. In 60% of cases, the private costs of emissions abatement were negative, indicating that this environmental benefit was achieved at a profit.
4. Distributed large solar installations on rooftops are environmentally preferable to centralized solar PV generation.
5. As Digital Solar drives greater panel adoption, Australia is in need of a solar panel recycling policy to manage the potentially negative end-of-life impacts of the technology.

6.0 PILLAR 3: ECONOMIC FEASIBILITY

Evaluating the financial performance of Digital Solar is key in understanding its feasibility for implementation in strata buildings. If financial performance is not sufficient, there is little chance of attracting initial investors, nor voting support from the Owners Corporation. Determining feasibility involved the combination of primary financial data from bills, interviews and Wattblock spreadsheets with information collected and synthesized from literature. This process culminated in the development of several financial calculators, examples of which are presented in Appendix C.

6.1 METHODOLOGY:

This section will present a brief description of the key steps involved in determining financial feasibility and building calculation spreadsheets. The process diagram below describes the flow of data through the calculation spreadsheets that were developed.

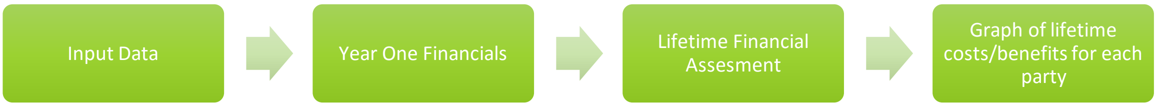

Figure 20: Process diagram for data flow through calculation spreadsheets.

Key inputs for calculation of financial feasibility are presented in table 11. The diagram below describes in greater detail the flow of input data through the calculator, with inclusion of the three key stakeholders: Trust investors, Owners Corporation and Residents. This diagram also describes the key outputs of the calculation, including lifetime financial charts and lifetime financial graphs for each stakeholder.

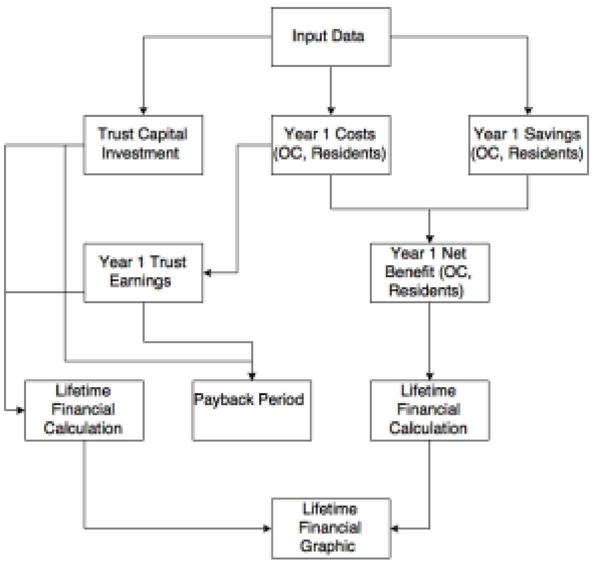

Figure 21: Detailed process flow diagram for calculation spreadsheets.

Table 11: Key data inputs for calculation of financial feasibility.

Input	Assumed Value	Notes	Source
Number Apartments	Varies		Site building plans
Digital Solar Output (kWh)	Varies		Digital Solar Size data sheet (see Pillar 1)
Feed In (kWh)	Varies		Digital Solar Size data sheet (see Pillar 1)
Digital Solar Sale Price	Varies		-
Grid Price	Varies		Building energy bills
Feed in Tariff	$0.08		Wattblock Data Sheets
Matter Fees	$9.90 per month		McGregor (2016)
System Size	Varies		Digital Solar Size data sheet (see Pillar 1)
Daytime Common Usage	Varies		Wattblock data spreadsheets
Daytime Leftover Solar Production	Varies	Indicates remaining solar production that can be used to supply apartments	
Cost per kWh	$1.32	Brisbane pricing estimate for Sep 2016	SolarChoice (2016)
Digital Solar cost per apartment	$1397		McGregor (2016)
Number of Panels	Varies	Based on assumption that each panel is 0.25kw	AGL (2016)
Annual Clean Cost Per Panel	$5.00		Wattblock data spreadsheets
Annual Inspection Cost	$150.00		Wattblock data spreadsheets
Inverter Replacement Cost	Varies		Wattblock proprietary formula

Following is a description of the key formulas used within the calculator to determine financial feasibility.

Net Present Value:

Net present value was calculated to indicate the net financial benefit of Digital Solar to trust investors. Net present value compares the present value of future cash flows against the present value of future cash outflows, and as such accounts for the time value of money. This is critical, as an understanding of the future benefits received will allow investors to make more informed investment decisions. Where the NPV is positive, the Digital Solar generates a net return for investors over the project lifetime.

$$NPV = \sum_{t-1}^{t} \frac{Net\ Cash\ Inflow_t}{(1 + Discount\ Rate)^t} - Investment\ Costs$$

where t is the number of time periods

The discount rate for this calculation is set at 9.5%, which is equivalent to the annual interest paid on a Macquarie Bank loan; the benchmark figure used in Wattblock's financial assessments.

Yearly and Cumulative Net Benefits:

Net benefit is a measure of financial revenue minus any expenditures, and is a vital tool to effectively evaluate savings potential for Owner's Corporation and Residents.

$$Net\ Benefit = Total\ Savings - Total\ Costs$$

Total savings are considered to be the savings that Owners Corporation and Residents accrue compared to the price they would have paid to consume the same amount of electricity at grid prices.

Total costs cover factors such as Digital Solar service fees, panel maintenance and inspections.

Payback Period:

The payback period describes the amount of time a project takes to recover initial capital investment. It is a vital tool for comparing energy efficiency projects, as it is a relative measurement and therefore useful for comparison. Generally, projects should be prioritized with fastest payback undertaken first. Payback period is one of major ways projects are assessed in Wattblock's reports and hence is important to measure to include in this report.

$$Payback\ Period = \frac{Yearly\ Benefits}{Initial\ Capital\ Invesment}$$

Internal Rate of Return:

Internal rate of return (IRR) expresses the percentage rate earned on each dollar for each period that it is invested. IRR is calculated by finding the discount rate that sets the NPV to a value of zero. That is, the interest rate that would result in the present value of the capital investment, or cash outflow, being equal to the value of the total returns over time, or cash inflow. The IRR is a metric that can be used to compare the relative return on investment for different energy efficiency projects.

$$O = \sum_{t-1}^{t} \frac{Net\ Cash\ Inflow_t}{(1+Discount\ Rate)^t} - Investment\ Costs$$

Financial Scenario:

The Digital Solar financial calculator is constructed in such a way that it can optimize for several different financial statistics, and explore how these impact lifetime financial performance for Owners Corporation, Solar Trust and Residents.

A list of example scenario's/investigations that can be explored through the calculator are presented below:

- Optimizing financial return and payback period for the Trust
- Optimizing the sale price of electricity from Trust to Owners Corporation and Residents such that it delivers most benefits to the selected party of choice
- Entering a desired net benefit for each party in year one and computing the optimal sale price to achieve this
- Optimizing Trust returns to achieve a desired NPV

For any given analysis of financial feasibility using this model, a given set of decisions rules or scenario needs to be selected. For the financial assessment in this report, the following rules were set:

- Maximize sale price of solar energy from Trust to Owners Corporation, subject to the condition that residents *never* pay more for their electricity consumption when compared to an equivalent amount purchased from the grid. In most cases, this sets the Year 1 net benefit of residents to $0, or a price at parity with grid electrical consumption.
- The price of Digital Solar generation/kWh does not exceed the grid price of electricity

This scenario was selected because it represents a realistic set of constraints when implementing Digital Solar. The ultimate decision to implement the technology lies in the hands of the Owners Corporation, any technology that increases electricity prices for all residents (whilst allowing large returns for the initial Trust investors) is likely to be extremely unpopular and would not receive voting support at annual meetings.

6.2 RESULTS:

The financial feasibility of Digital Solar was highly variable, as demonstrated in table 12.

Payback period varied widely, with the shortest period being 9.43years. On average, the payback period of Digital Solar systems is significantly longer than that of standard solar installations. This is largely because of the following factors:

1. Initial capital investments are much larger
2. The aggregate financial benefit of avoided grid consumption is divided between multiple stakeholders, whilst only one party (the Trust investors) bear the initial investment cost.

Building 10, returned an infinite payback period, because the initial investment cost was not recovered under the scenario conditions specified This is represented visually in appendix B

As the table indicates, several buildings: 3,5,6 and 10 delivered negative NPV values. As such, Digital Solar implementation in these buildings is not financially viable, as investors are unlikely to become involved if the project will generate no returns. Figure 22 compares the proportion of financially feasible sites to those that are not.

For residents, the assumed scenario consistently generates positive net benefits over the lifetime of the solar panel. The average financial net benefit was $135,210. The greatest of these was achieved at Building 10, where the positive benefit to residents over the lifetime was worth $311,830. The Owners Corporation also received positive net benefits across all case study sites, though these were on average much smaller than the residential benefit, at $42533 over the system lifetime.

Table 12: Lifetime financial analysis for Digital Solar in strata.

Building	Payback (Yrs)	Trust NPV ($)	Cumulative Residential Net Benefits ($)	Cumulative Owners Corporation Net Benefits ($)	Cumulative Trust Net Benefits ($)
Building 1	9.43	13,579	75,197	16,726	131,288
Building 2	15.39	15,154	93,039	45,400	146,517
Building 3	88.95	-3,418	33,408	26,284	-33,046
Building 4	24.668	5,769	137,853	68,100	55,780
Building 5	38.94	-1,894	261,202	32,258	-18,314
Building 6	2364.51	-22,067	237,403	72,879	-213,354
Building 7	14.67	18,132	48,960	53,763	175,309
Building 8	19.12	3,106	35,762	14,337	30,031
Building 9	12.65	31,609	117,472	68,100	305,611
Building 10	∞	-37,934	311,830	27,479	-366,755

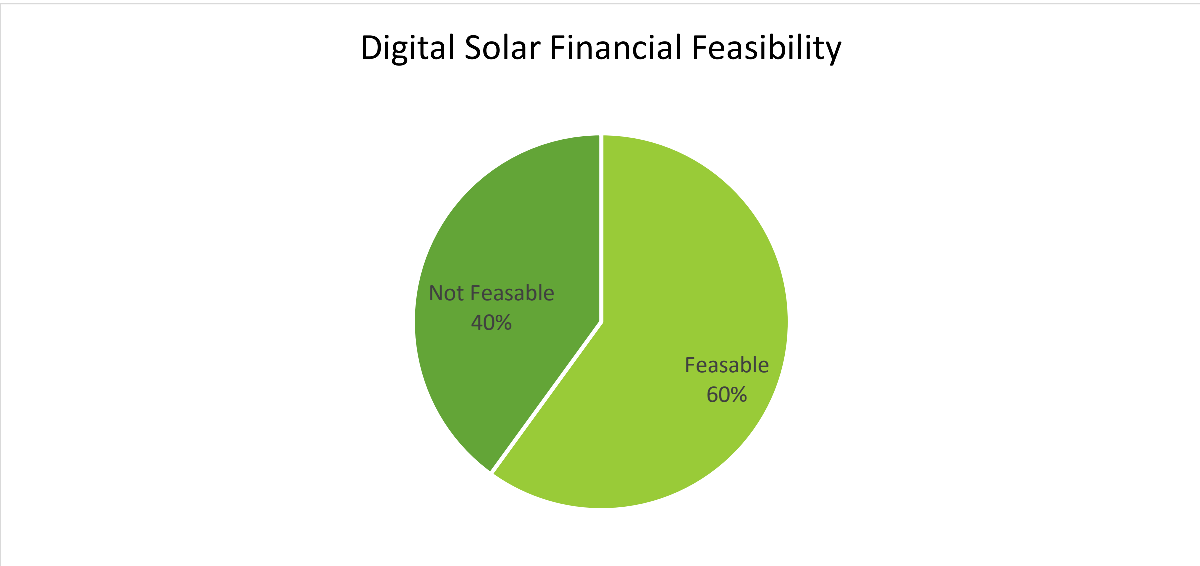

Figure 22: Proportion of feasible and not feasible buildings in the study.

Figure 23 provides an example of the lifetime financial returns for the Digital Solar system installed at Building 1. This graph clearly illustrates the distribution of finacial benefits over the lifetime, reveals the payback period of the system for trust investors (where the Trust finacial benefit crossses the X-axis and illustrates the finacnial impact of key maintenace activites, such as inverter replacement at year 10. A list of lifetime financial graphs for each building is presented in appendix B.

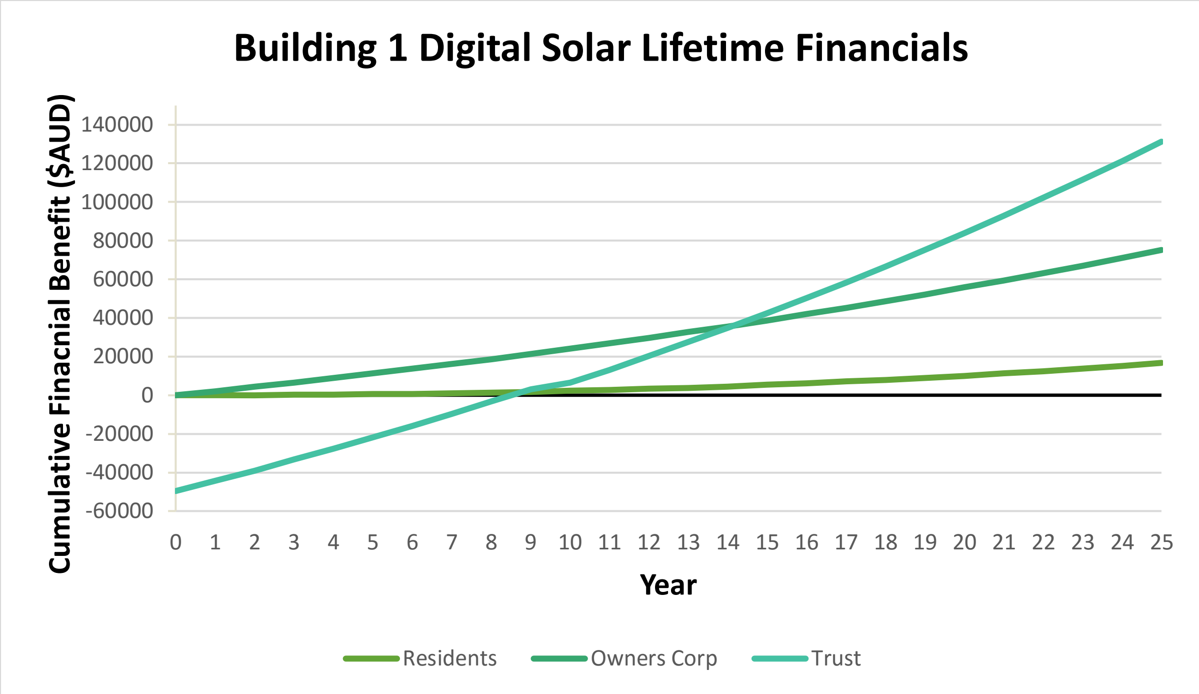

Figure 23: Lifetime financial graphic illustrating the cumulative financial benefit for each stakeholder.

6.3 DISCUSSION:

This section will explore the critical factors that determine financial feasibility of the Digital Solar panels in strata buildings. As described in the results section only 60% of buildings were found to be financially feasible (i.e. positive NPV) when Digital Solar is installed.

The table below presents the correlation coefficient between project NPV and several other building or financial characteristics.

Table 13: Association between NPV and building/financial characteristics.

Variables	Pearson's Correlation Coefficient
Initial Capital Investment (CAPEX) and NPV	0.236
Digital Solar Sale price/kWh and NPV	0.83
Size (kW) of Digital Solar System	0.26
Yearly Trust Earnings and NPV	0.96
Daytime solar consumption per apartment (kWh) and NPV	0.79
Roof Area Per Unit (m^2) and NPV	-0.77

Initially, it was anticipated that building type (i.e. low, medium, high rise) would have a strong impact on the overall financial performance of Digital Solar. However, as the figure below indicates, there is no clear pattern that emerges between these factors. This may be due to a skewed data set and warrants further investigation in future studies with a more comprehensive sample size.

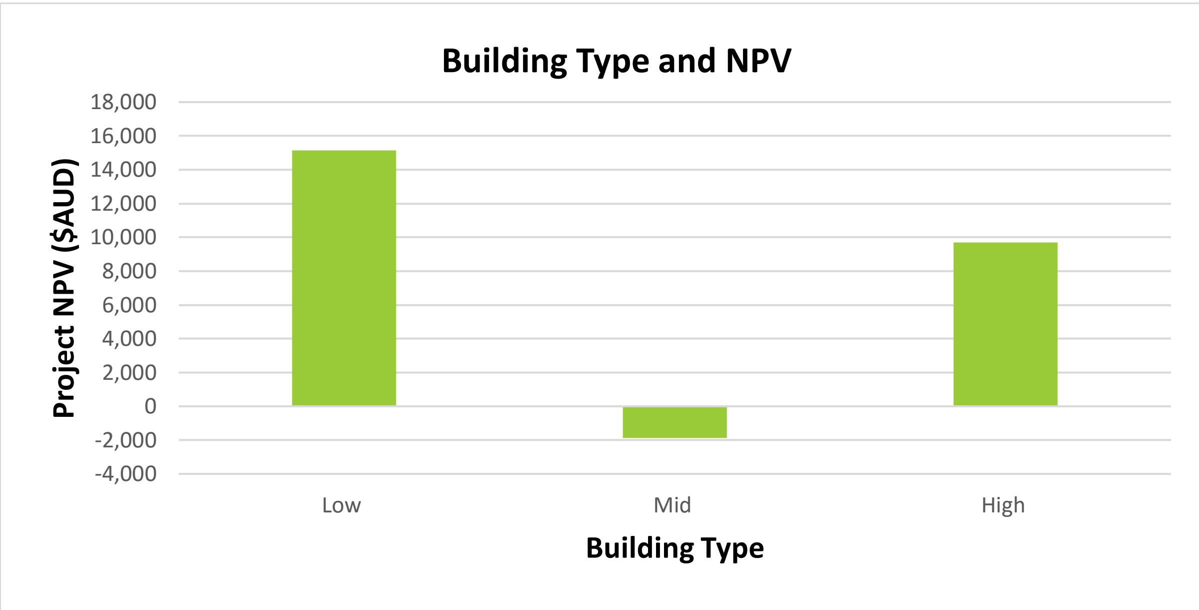

Figure 24: Building type (Low, Medium or High Rise) and NPV

Maintenance fees were found to have a minimal impact on the lifetime financial performance of Digital Solar. Major financial impact occurred in year 10, when it is assumed that a replacement of the main inverter will be required. Larger systems have a greater replacement cost. The financial effect of inverter replacement is reflected in the lifetime financial graphs (appendix B), and can be seen as a plateau in the in the cumulative financial benefit for Trust investors in year 10.

As table 13 indicates, the size of the Digital Solar system has a weak positive association (0.26) with project NPV. This is largely because the additional sales of electricity from a larger solar array are offset by increasing system and maintenance costs. Initial setup costs are particularly high in cases where there are a large number of apartments. Digital Solar financial feasibility appears weakest in buildings with a large number of apartments but a relatively small Digital Solar array (or small increase in size relative to what is possible with a standard solar installation), as there is not enough additional energy production to offset the aforementioned setup costs. The positive financial benefits of a Digital Solar installations are most beneficial when residential energy consumption per unit is highest, as this allows additional 'headroom' within the load profile to install large solar whilst avoiding grid feed-in, thereby generating returns equal to the Digital Solar sale price/kWh. The 4 sites that have the highest energy consumption per apartment show a much stronger positive association (0.78) between system size and NPV.

Though project capital investment (CAPEX) has a significant impact on the payback period, the data indicates only a relatively weak association (0.24) between it and project NPV. This is because a larger investment generally results in a greater number of panels that enable the sale of more energy between Trust and Owners Corporation/Residents, offsetting capital requirements. However, in cases such as Building 10, roof space limits the installed size of the Digital Solar to just 9.6kw; a small system in comparison to others in this sample. Despite the modest size of the Digital Solar system, the Trust must still pay the setup costs for all 23 apartments in the building. As such, the capital investment required for Digital Solar is much greater than the benefits of avoided grid consumption, as shown in figure 25 below. This is a key driver of the poor financial performance and long payback periods at this property.

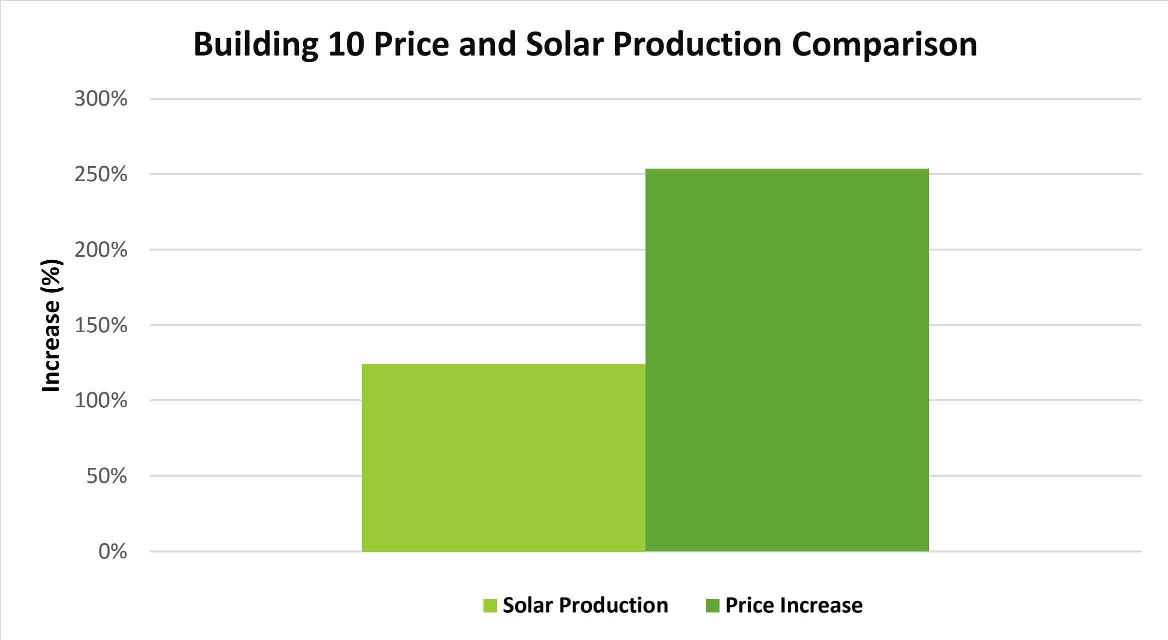

Figure 25: Comparison of energy production and price increases when upgrading too Digital Solar at Building 10. .

Building 10 indicates that it may not always be most beneficial to utilize 100% of available roof space to install solar panels, or to install the maximum possible size that Digital Solar allows. As indicated by Building 10 a situation where the ratio of apartment to roof-area is large, there are unlikely to be desirable financial returns. Under these conditions, a smaller Digital Solar or standard solar system is best adopted. Future studies into this technology could model this relationship with the aim of finding producing a model that optimizes system size based upon number of apartments, roof space and rates of energy usage.

Table 13 indicates that Trust yearly earnings from the sale of electricity are almost perfectly correlated with project NPV (0.96). Earnings are determined by the revenues received from the sale of electricity to Owners Corporation and Residents, less the annual panel inspection and maintenance fees. The sale price of electricity from the Trust to Owners Corporation is a key driver of the yearly revenue that the Trust receives. Sale price is in turn driven by the grid price of electricity, as the scenario constraints state that solar generation price cannot exceed the grid price. Table 13 demonstrates the strong positive association (0.83) between high grid price and NPV. The higher the grid price of electricity at a property, the higher the sale price of Digital Solar can be without violating our scenario constraints, and the higher the corresponding annual earnings. This means that, where a property has already negotiated low electricity rates or uses a bulk billing arrangement (where bulk purchases of electricity for the entire building lower the unit price), the financial viability of Digital solar is reduced.

The sale price of Digital Solar electricity is also constrained by the scenario rule that residents must never pay more than the grid price for an equivalent amount of energy. In other words, the net benefit for residents can never be negative. Residential net benefits are comprised of the savings that are achieved by purchasing solar energy at rates lower than the grid price, less the cost of

Digital Solar monthly fees. Though these fees total just $118/annum, in aggregate they often comprise a substantial portion of the savings that are achieved by Residents through avoided grid consumption. For the buildings in this study, the average aggregate Digital Solar fees per year are equal to $4330.

As such, a key way to increase the financial viability of Digital Solar installations for both Residents and the Trust is to alter the existing fee structure. For example, it may prove beneficial (in net terms) to offset or subsidize the fees that Residents pay using a portion of the earnings received by the Owners Corporation. Alternatively, a 'bulk-billing' arrangement for Digital Solar could be negotiated to reduce the fees paid per resident in larger strata buildings. Reducing the fees that each resident pays for Digital Solar increases their net savings per annum, and hence offers a greater 'price ceiling' for the sale of energy generated by the Digital Solar panels, optimizing the project NPV and return on investment that Trust investors receive.

It is important to note that many of the findings of this financial analysis are dependent on the scenario constraints. This is because changing the scenario effectively alters the way in which the aggregate financial benefits of Digital solar are distributed amongst the Trust, Owners Corporation and Residents. In essence, selecting different scenarios changes the way in which the aggregate benefits of digital solar are distributed between the parties. It is recommended that future studies investigate different scenarios and conduct a sensitivity analysis on key financial metrics such as project NPV and cumulative benefits. This will lead to a more complete picture of the factors that consistently impact the financial performance of Digital Solar in strata. Regardless of the scenario selected, the underlying financial benefit of Digital Solar remains: parties can save money by avoiding grid consumption, the costs of which are expected to rise because of the factors outlined in section 2.1 and 2.2.

6.3.1 PILLAR 3 REVIEW: KEY FINDINGS

1. Digital Solar proved to be financially feasible in 60% of cases
2. In some cases, it may not be optimal to install the largest Digital Solar system possible
3. Adjustment of fee structure is a key way to improve financial performance
4. A low grid price or bulk-billing agreements can constrain the returns received by Trust investors
5. Future studies should examine financials feasibility under different scenario's and conduct sensitivity analysis to establish factors that consistently impact financial performance

7.0 PILLAR 4: FOSTERING A DISTRIBUTED POWER MODEL

Having assessed Digital Solar against economic and environmental criteria, it is possible to evaluate the contribution that technology makes towards a distributed energy transition; the key structural change to energy markets discussed in section 2.2. This discussion will evaluate Digital solar against its ability to achieve the key benefits of distributed generation (such as increased resilience, lower emissions, and democratization of the energy market), as well as its ability to address identified technical issues in the existing grid infrastructure.

As discussed in Pillar 1, Digital Solar can provide a framework which reestablishes the incentives to adopt larger solar systems in strata. It achieves this by enabling the sale of solar energy to residents in private apartments, thereby bypassing the need to feed excess generation into the grid at low prices. This universally lead to an increase in the viable size of solar installations and increases in the amount of rooftop area utilized for production of solar energy. Digital Solar is also able to address key practical issues that constrain solar adoption in the strata marketplace including landlord-tenant concerns, perceptions of poor value and high transaction costs.

For a transition to distributed solar generation (DSG), these are important advances. This Is primarily because the Digital Solar platform can enable solar adoption in a way that ‘bypasses’ some of the current structural market barriers, ineffective Government policies and industry opposition tactics that constrain the shift to distributed generation.

The following describe the key structural problems that Digital Solar is able to address:

1. The ‘real’ economic benefits of localized self-generation are undervalued in Australia. For example, the IEA (2002) states that on-site production could result in smaller transmission and distribution costs, potentially reducing the cost of electricity by as much as 30%.
2. Current subsidy schemes such as the RET and Feed-In tariffs are expensive economically inefficient ways to foster widespread adoption of distributed energies (The Centre for International Economics 2013)
3. It is difficult for regulators or subsidy schemes to accurately determine the appropriate subsidy or incentive scheme to achieve a given level of adoption (Pepermans et al 2005).
4. The centralized and monopolist sale of energy in Australia allows for easy discouragement of distributed generation. This is achieved through high prices for ancillary services or by offering low prices for distributed generation that feeds to the grid (Electric Power Research Institute 2011) .

By re-establishing an incentive mechanism that is independent from either Government subsidy programs or the operation of major energy generators, Digital Solar represents a significant step in overcoming the structural undervaluation of DSG and fostering greater adoption. In cases where the technology is financially beneficial for all parties, Digital Solar’s transaction model promotes energy *independence,* which leads to enhanced resilience of energy supply and protection against price volatility (Kaundinya et al 2009). Thus, Digital Solar is able to address problems with systemic undervaluation of distributed generation (by simply creating these values privately) and provides a viable path towards solar energy that is more independent from Government policy and 'see-sawing' political sentiment. Furthermore, Digital Solar addresses issues concerning efficiency and inaccuracy as noted in point 3 above. As a private transaction, individuals have more information and are thus able to make better decisions and optimize the quantity of solar installed for their properties far more accurately than any generalized subsidy or incentive scheme can (Macintosh & Wilkinson 2011).

As illustrated, widespread adoption of Digital Solar has the potential to make significant advances towards emissions and renewable energy targets; without the use of policy instruments. The independence of Digital Solar transactions also means that established energy companies are less able to actively discourage the move towards distributed generation, as an increased proportion of energy usage can be sourced from the panels and priced according to individual building conditions. As illustrated in the financial analysis, increasing grid prices enhance the net benefits and NPV achieved by installing Digital Solar. However, energy companies may simply cover falling energy demand by increasing prices for those who do not have solar installed. Thus, whilst Digital Solar is highly beneficial to users and promotes energy independence, it may also exaggerate market inequalities and could potentially have a high social cost. In this way, Digital Solar achieves little in respect to democratization of energy markets, enhanced market equality and participation.

In its current state, whether or not the technology can lead to more equal participation in energy markets largely depends on the adoption rate and the conditions under which investors and Owners Corporations elect to manage the system. The current legal complexity required for its implementation in strata means that Digital Solar could be operated in a way that may actively enhance market inequality; effectively isolating its users from the wider marketplace and creating fragmentation. This would do little to encourage the involvement by all parties to generate a truly distributed, democratic and 'peer-to-peer' energy network (Rifkin 2011). Future research into Digital Solar in a policy context would do well to evaluate the true social costs of the technology, especially in comparison to other renewable technologies, and energy efficiency options.

Similar issues concerning equity and fair participation emerge *within* strata buildings as well. Whilst the management structure and voting mechanisms in strata law ensure at least some participation from all parties is assured, the flow of energy between producers and consumers remains one-directional. Thus, whilst Digital Solar may achieved greater adoption of distributed energy generation, it does not necessarily represent increased democratization and equality within buildings. Without established regulation and defined parameters for determining how benefits are distributed, the system has significant potential to create inequalities. This uncertainty can create perverse incentives for Digital Solar adoption among strata buildings (Peek 2005).

Though Digital Solar can be effective at addressing some of the structural problems concerning the shift towards distributed generation, the technology does little to address the many technical and infrastructural issues that currently constrain adoption, and represents little advancement towards enabling democratic sharing of energy in a physical capacity.

For example, a key problem that currently limits distributed adoption is the fact that existing grid infrastructure is poorly designed to handle two-way power flows. This leads to problems with efficient, stable and high quality power supply between distributed generators and the grid network. Currently, bi-directional power flows make it difficult for market operators to design and tune the protection systems in the grid. This can lead to short circuiting and over-loading incidents where neither producing or receiving parties will detect the anomaly and shut down (as per normal operating protocols) (Lenseen 2000). This can cause damage to grid infrastructure and/or electrical equipment, and lead to 'islanding', where a local distributed generator may keep a section of disconnected grid energized, presenting a real safety risk to repair personnel (Ropp et al 1999). As Digital Solar simply tracks and meters the usage of energy and reestablishes incentives to install larger systems, it does little to overcome these technical problems.

Digital Solar can provide resilience in respect to pricing, by increasing independence from energy market fluctuations, but it does little to improve resilience with respect to the stable supply of electrical energy. As Lombardo (2013) points out, for a system to be considered truly independent, it must be designed such that it can independently produce, distribute and store energy during grid outages and natural disasters. As Digital Solar itself does not facilitate the provision or storage of electricity, it does not contribute towards this aim. Further, most grid-connected solar PV systems require automatic disconnection from the grid during a power outage. Because the majority of solar systems are not yet designed to function as both a grid-connected and stand-alone system, they will simply stop generating. Digital Solar does not facilitate the management or storage of energy usage and hence cannot overcome this problem.

Whilst Digital Solar may do little to address these key physical issues, it represents a highly effective accounting and management system that lays of framework within which other technologies, such as battery storage and smart metering are able to add functionality. Working in concert with battery storage technology for example, significantly increases energy resilience, grid independence and can enhance the utility of Digital Solar by enabling peak demand management (Reedman 2015). Such an implementation would also reduce load on the grid and minimize instances of over-loading during period of high bi-directional power flow (Ropp et al 1999). Digital Solar is effective in that is has the potential to enable advanced management of both solar and other ancillary technologies in ways that add value (by increasing system size and participation in the marketplace) compared to centralized power systems. This is key in tilting the energy generation landscape further in favor of distributed power systems.

Because of these factors, Digital Solar could be a key technology for utilization in what many view as the future of distributed energy; Virtual Power Plants. A virtual power plant (VPP) is a group of distributed power technologies that are aggregated and operated in unison by a centralized control system powered by the Internet (Zurborg 2016). An example of VPP architecture is illustrated in figure 26.

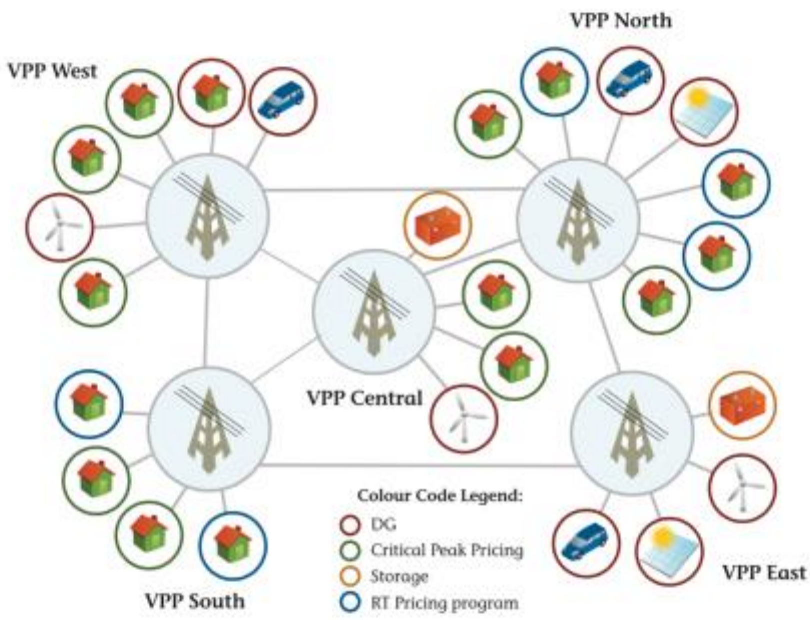

Figure 26: System diagram of virtual power plants (Zurborg 2010).

Centralized control and operation extend the capabilities of individual distributed power units by enabling groups of grid-connected VPP's to deliver electricity to the transmission network in unison, during periods of peak demand, thus removing much of the increased strain that could otherwise be placed on grid architecture as distributed generation increases (Zurborg 2010). A VPP encompassing multiple strata communities could serve as a substitute for a single large power plant. In a VPP, individual distributed power units would be more flexible and quicker to react to fluctuations in electricity demand. Digital Solar, with its capability to precisely track and meter energy usage, pre-existing cloud integration and gateway that is capable of gathering data from up to 256 meters would be ideally placed for implementation in a VPP system. As with solar PV, Digital Solar may be able to provide a billing system that establishes incentives to adopt VPP's; an area worthy of future investigation

7.0.1 PILLAR 4 REVIEW: KEY FINDINGS

1. Digital Solar leads to advances that are important in tackling some of the structural issues preventing the move towards distributed energy
2. Digital Solar increases independence from the grid which may provide benefits to users but could place a net social cost on other users and increase fragmentation in the energy market
3. The legal complexity of implementing Digital Solar in strata buildings reduces the contribution towards achieving energy democracy
4. Digital Solar does little on its own to address the wider technical and physical issues that limit distributed adoption
5. Working in concert with other technologies such as in Virtual Power Plants, Digital Solar can play an important role in transition of the market to a distributed model

8.0 CONCLUSIONS

This report has presented a preliminary investigation into Digital Solar, a new technology that facilitates the sale of solar energy to multiple stakeholders in strata buildings. The study comprised a sample of 10 strata buildings from throughout South East Queensland, and explored factors including economic and environmental performance of the technology, as well as its ability to contribute to wider transitions within Australia's energy market.

Investigation indicated that Digital Solar enables the installation of much larger solar systems in strata buildings, and that these increases in system size lead to corresponding environmental benefits in terms of emissions reduction. Because Digital Solar works with standard solar panels there was little difference in energy payback time, whilst the cost of abatement in social terms remains uncertain and lies outside the scope of this project.

Digital Solar was proven to be financially feasible in the majority of cases, but this feasibility was highly site dependent and influenced by a complex array of factors that make assessment of buildings in the real world a lengthy process; not ideally suited to Wattblock's reporting model. Financial benefits were often not distributed equitably between the parties involved. In some cases, the costs of Digital Solar far outweighed the financial benefits that the platform could provide, indicating that it may not always be financially optimal to install a system of the maximum allowable size.

As a distributed generation technology that provides incentives to install large solar energy systems, Digital Solar contributes to the overall adoption rate of distributed generation and can overcome many of the structural market barriers for individuals who install the system. However, without careful management and/or widespread adoption, Digital Solar could place disproportionate social cost on users who do not adopt, resulting in an increasingly fragmented energy market. Digital Solar drives increased energy distribution but not necessarily increased energy democracy, and therefore does not realize the full benefits of distributed generation. However, the use of Digital Solar in conjunction with other technologies such as battery storage and Virtual Power Plants significantly enhances the ability to overcome technical constraints and enhances energy democracy.

Ultimately, Digital Solar has the potential to overcome the barriers that prevent adoption of large solar systems and encourage the adoption of distributed solar PV in the growing strata market. In many cases, it is a worthy long term investment in energy security and emissions reduction for strata buildings that have already enacted more basic energy efficiency projects. Digital Solar represents an important incremental step towards a sustainable distributed energy market in Australia.

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10.0 APPENDICES

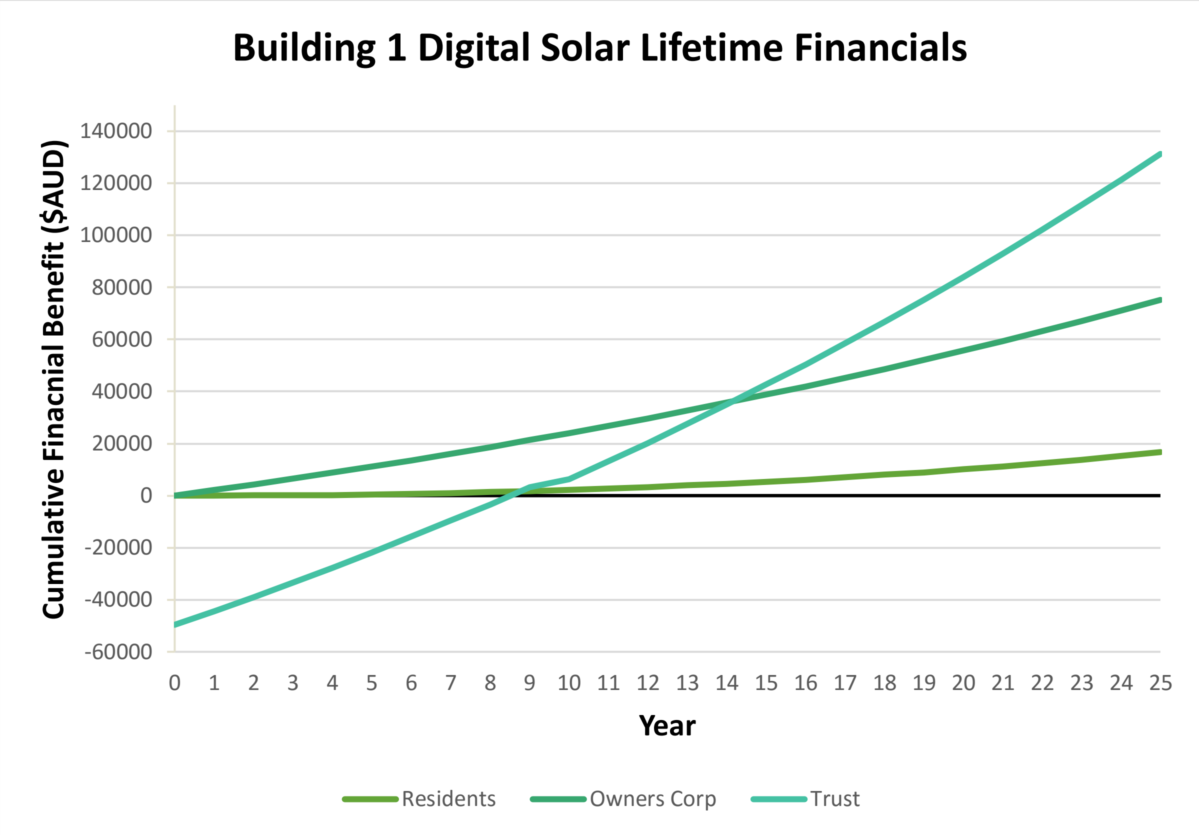
10.1 APPENDIX A:

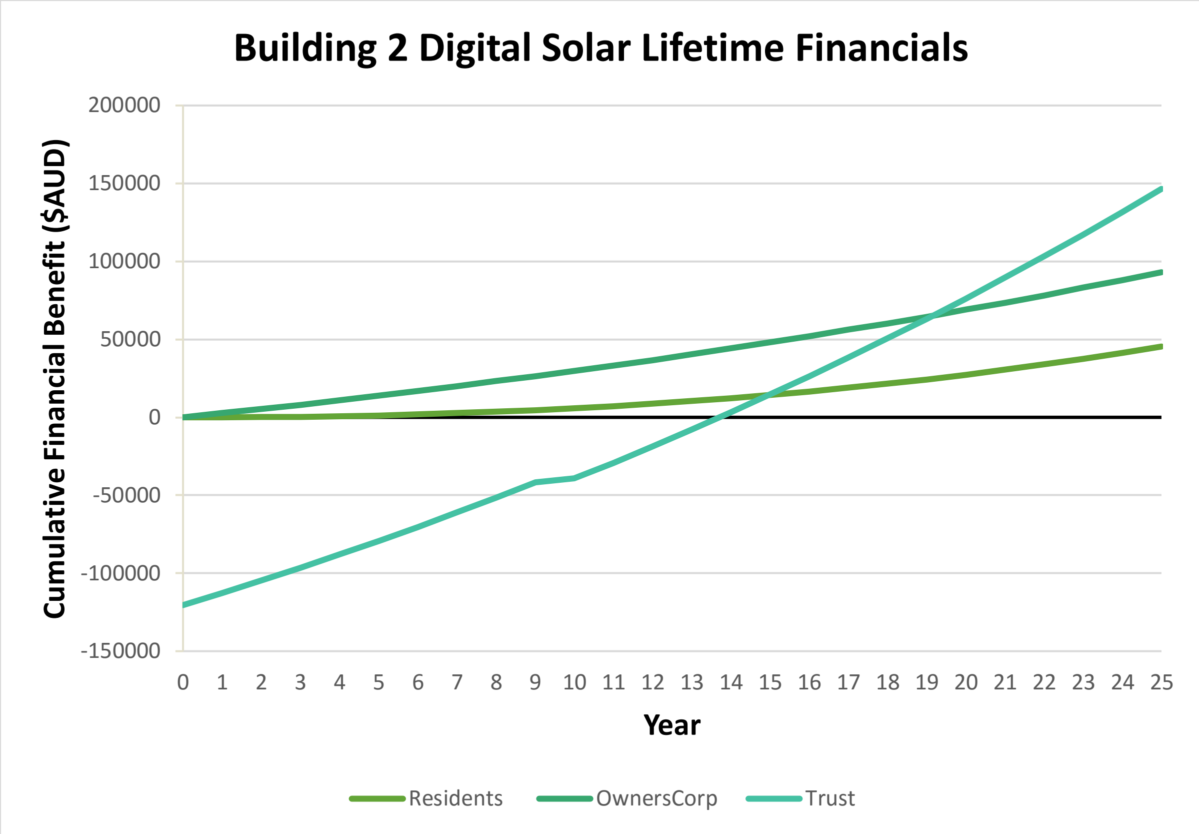
Appendix A presents the hourly energy consumption data used to construction the load profile graph presented in figure 11. This data is derived from Wattblock databases.

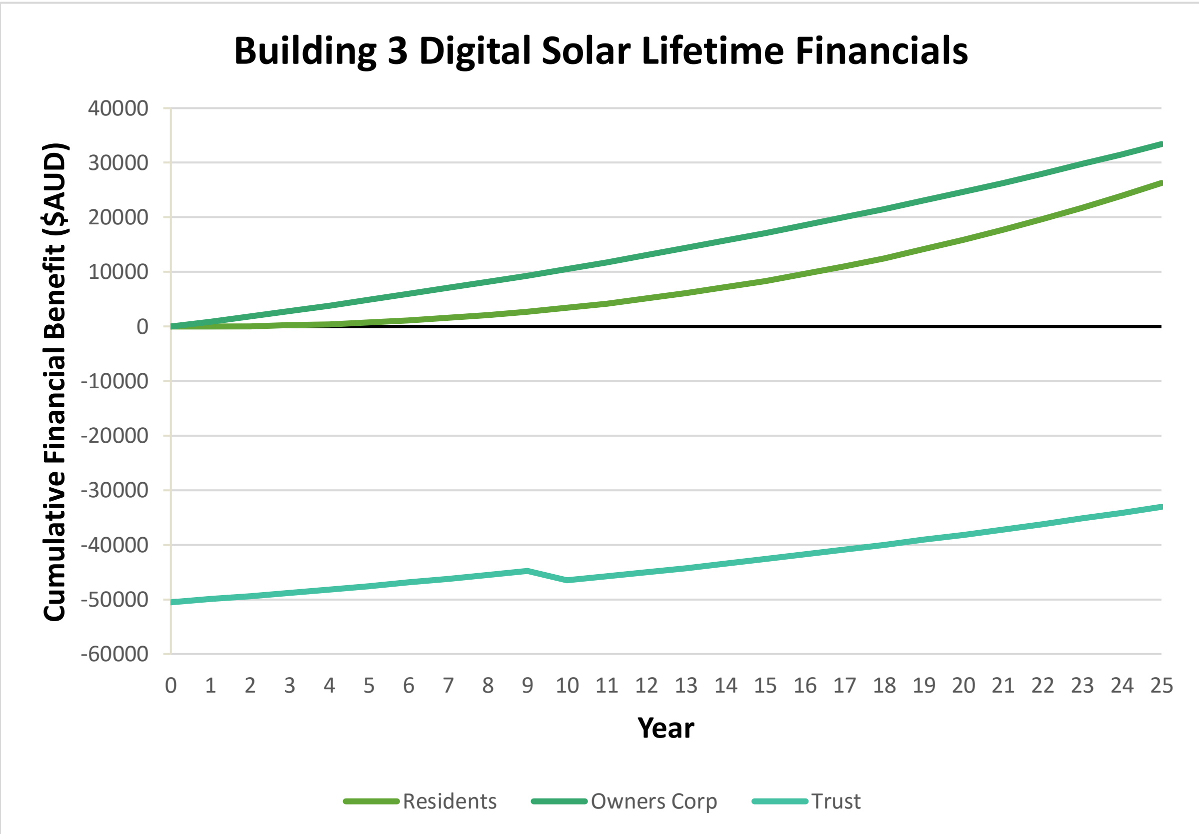
Hour	Usage (%) Total Daily Energy Consumption
1	3.15%
2	2.71%
3	2.47%
4	2.35%
5	2.33%
6	2.54%
7	3.13%
8	4.01%
9	4.35%
10	4.14%
11	3.97%
12	3.92%
13	3.94%
14	3.93%
15	4.13%
16	4.65%
17	5.71%
18	6.79%
19	6.84%
20	6.4%
21	5.79%
22	4.91%
23	3.92%

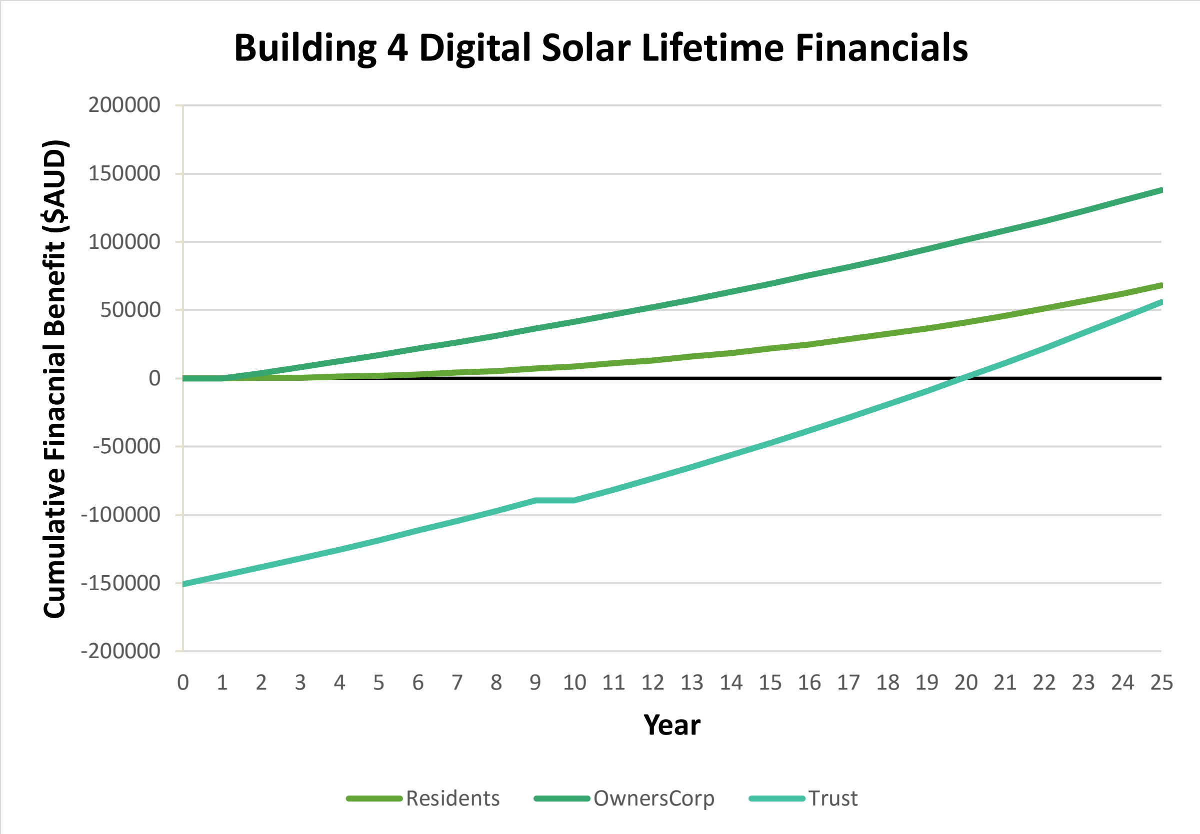
10.2 APPENDIX B

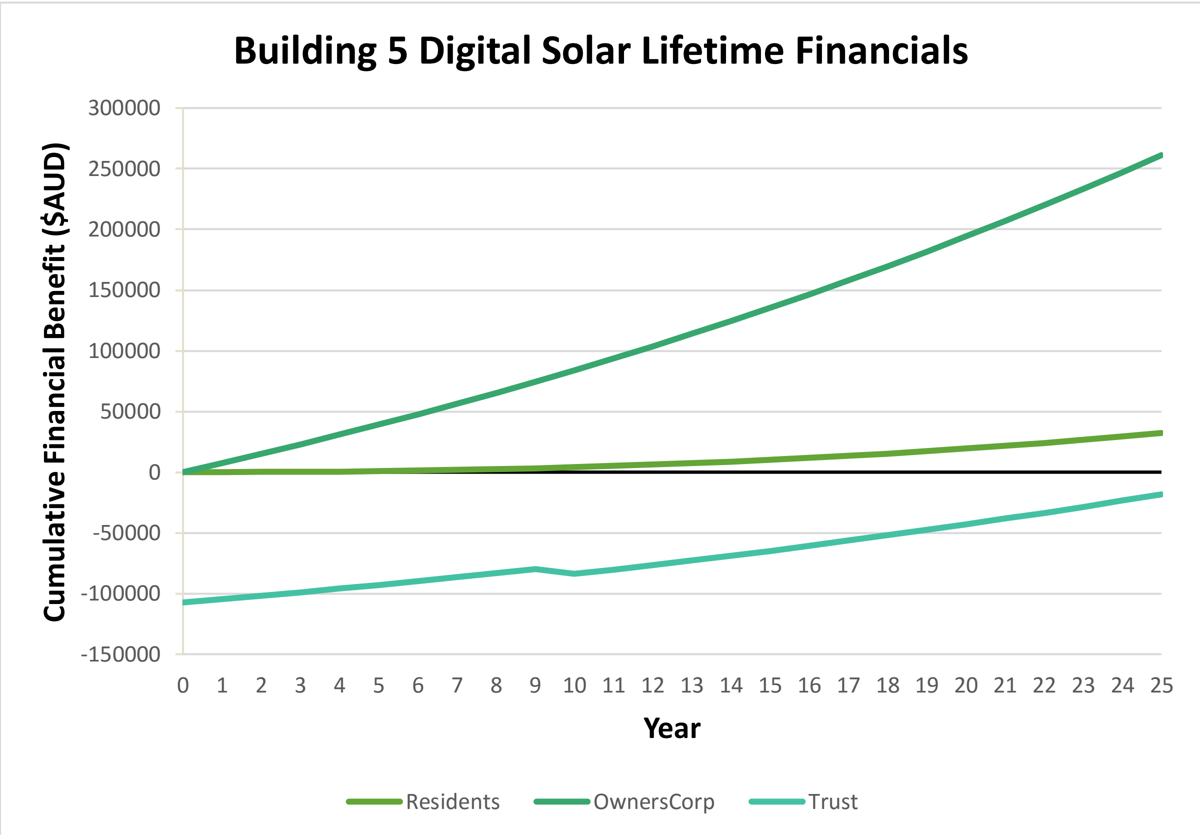
The following present the Digital Solar lifetime financials graphs for each property included in the study.

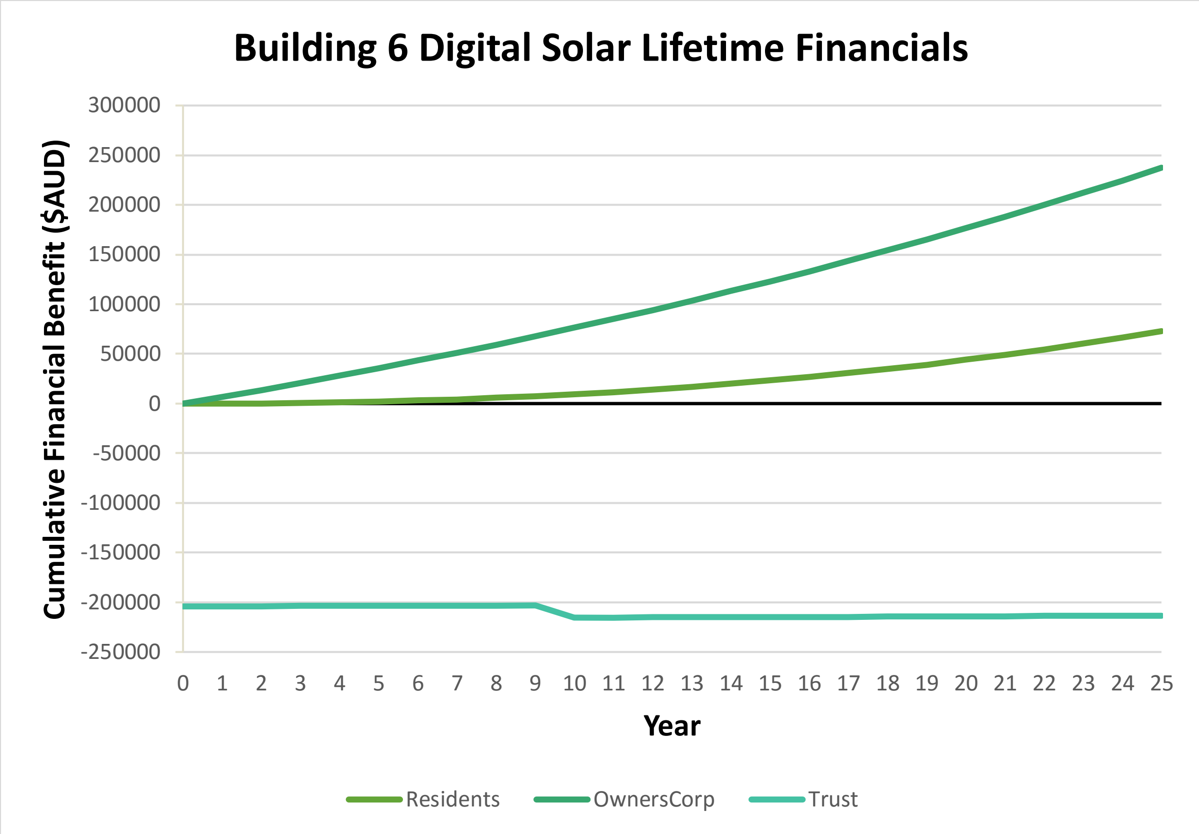


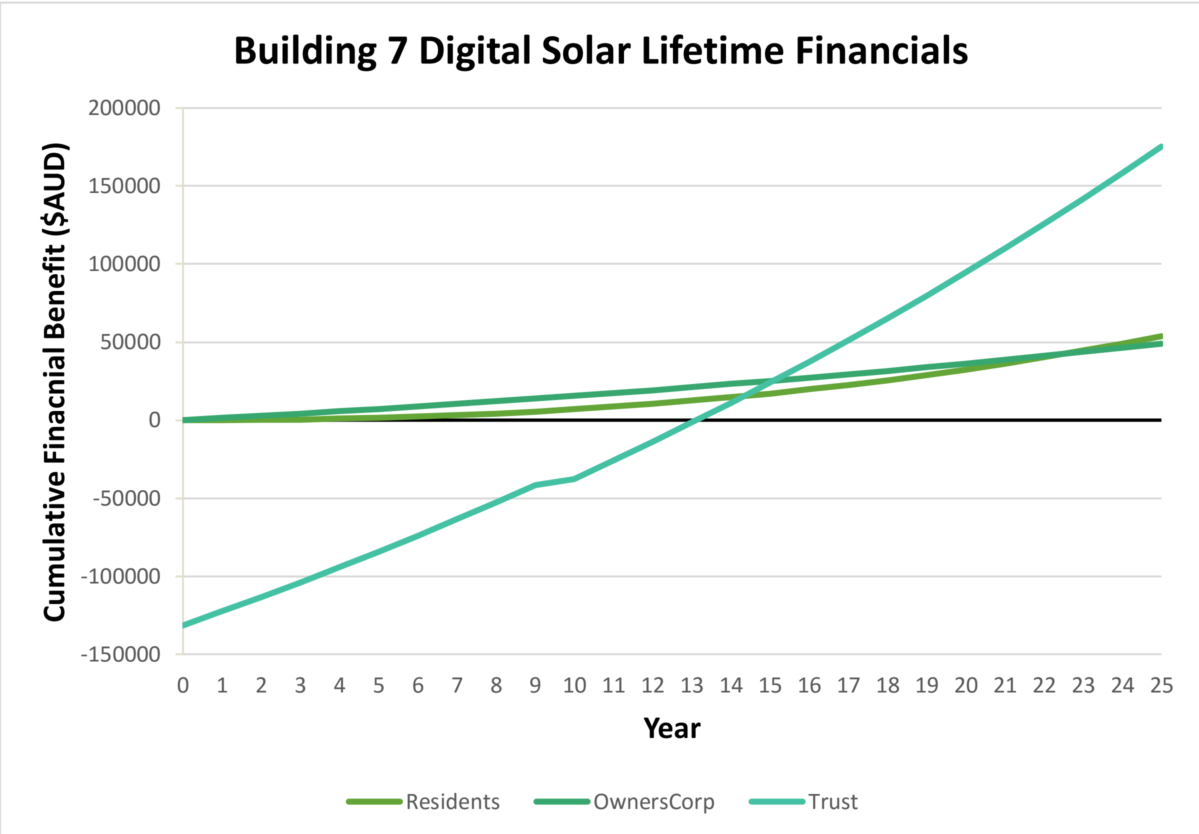

Building 2 Digital Solar Lifetime Financials
Cumulative Financial Benefit ($AUD)
200000
150000
100000
50000
0
-50000
-100000
-150000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Year
Residents
OwnersCorp
Trust

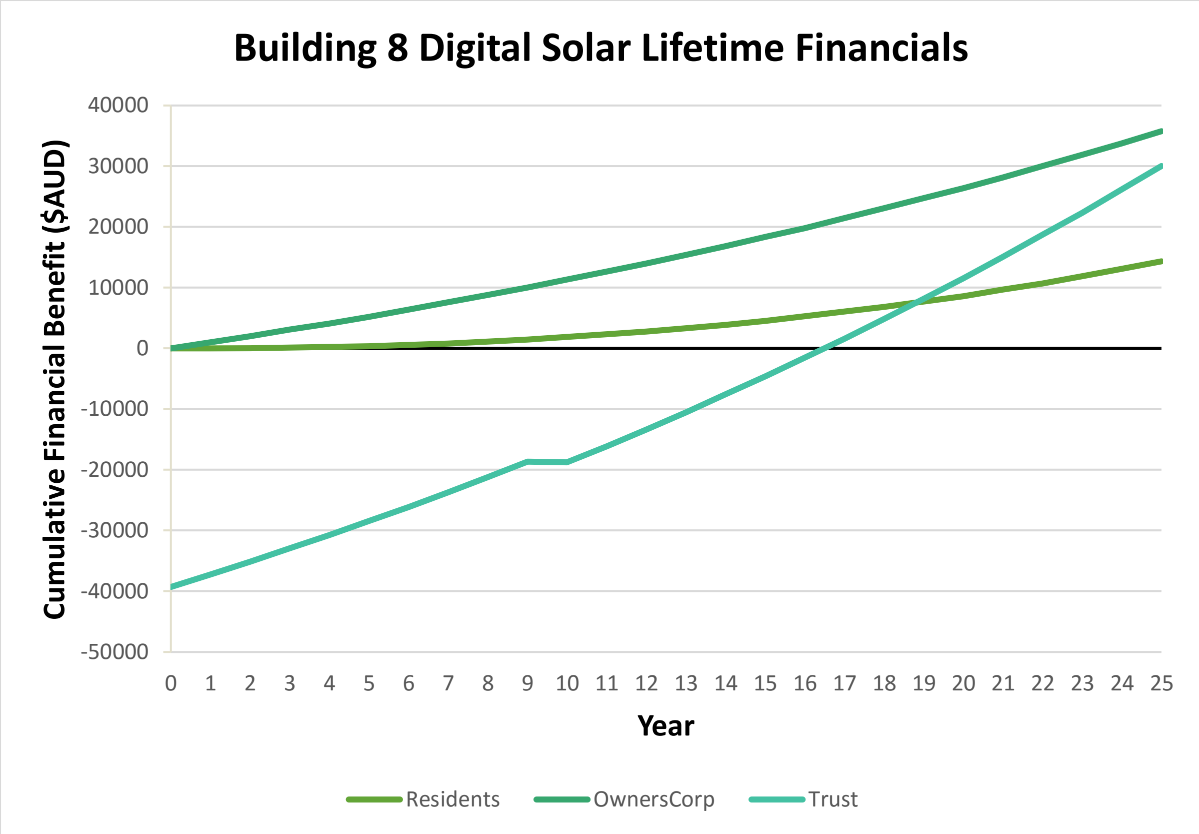

Building 3 Digital Solar Lifetime Financials
Cumulative Financial Benefit ($AUD)
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Year
Residents
Owners Corp
Trust

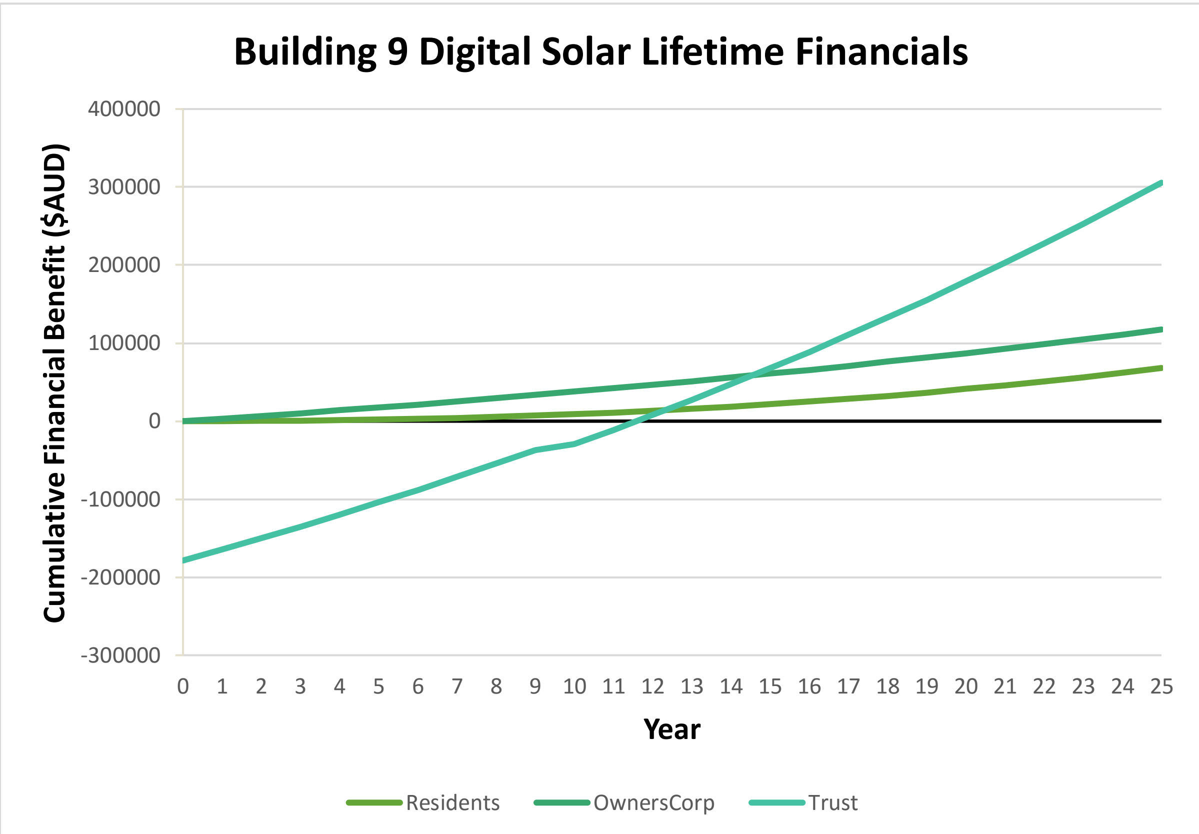

Building 4 Digital Solar Lifetime Financials
Cumulative Finacnial Benefit ($AUD)
200000
150000
100000
50000
0
-50000
-100000
-150000
-200000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Year
Residents
OwnersCorp
Trust

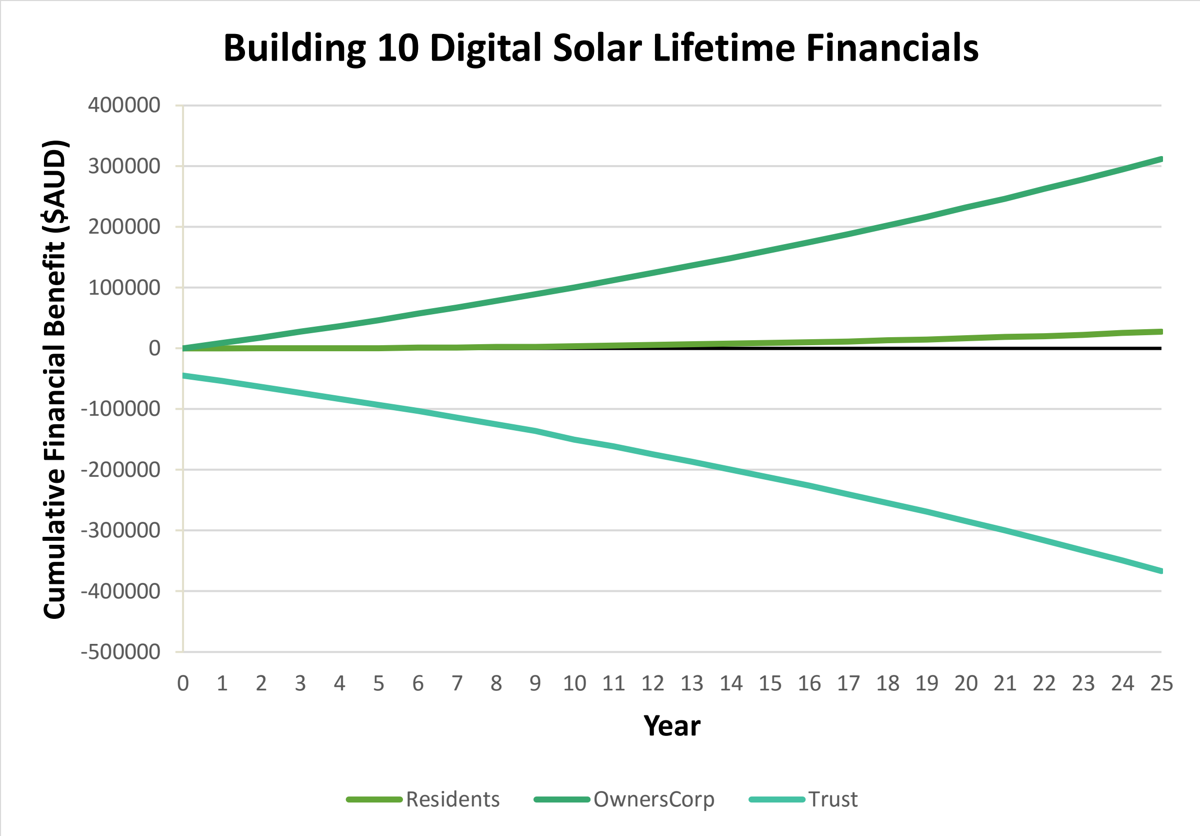

Building 5 Digital Solar Lifetime Financials
Cumulative Financial Benefit ($AUD)
300000
250000
200000
150000
100000
50000
0
-50000
-100000
-150000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Year
Residents
OwnersCorp
Trust


Building 6 Digital Solar Lifetime Financials
Cumulative Financial Benefit ($AUD)
300000
250000
200000
150000
100000
50000
0
-50000
-100000
-150000
-200000
-250000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Year
Residents
OwnersCorp
Trust


Building 7 Digital Solar Lifetime Financials
Cumulative Finacnial Benefit ($AUD)
200000
150000
100000
50000
0
-50000
-100000
-150000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Year
Residents
OwnersCorp
Trust


Building 8 Digital Solar Lifetime Financials
Cumulative Financial Benefit ($AUD)
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Year
Residents
OwnersCorp
Trust


Building 9 Digital Solar Lifetime Financials
Cumulative Financial Benefit ($AUD)
400000
300000
200000
100000
0
-100000
-200000
-300000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Year
Residents
OwnersCorp
Trust


Building 10 Digital Solar Lifetime Financials
Cumulative Financial Benefit ($AUD)
400000
300000
200000
100000
0
-100000
-200000
-300000
-400000
-500000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Year
Residents
OwnersCorp
Trust

10.3 APPENDIX C:

The following are examples of the Digital Solar financial calculator developed. The first image represents stage one in the calculator, where year one financials are calculated. The green region represents inputs, whereas the blue section indicates the calculator outputs. The second image displays the lifetime financial calculator, which calculates how benefits and costs accrue to each party of the lifetime of the Digital Solar system. The cumulative benefits for each party are the most important part of this calculator, the results of which are used to construct the lifetime financial graphs presented in Appendix B. The lifetime calculator includes cell shading to allow for easy visual identification of the cumulative benefits for each party. Deep red represents large negative benefit, and deep green represents significant positive benefits.

Inputs		Estimated Costs		Savings vs Grid Consumption		Net Benefit		Trust Financials		Check	
Number Apartments	57	DS System	$ 150,909.00	Resident	$ 6,771.60	Residents per apartment	$ -	Feed In	$ 37.44	Total Value	$ 18,216.58
DS Production (kWh)	81324	Cost of DS production	$ 7,310.02	OC	$ 4,134.95	OC	$ 4,016.15	Earning (annual)	$ 6,117.46	Summed Benefits	$ 18,216.58
Feed In (kWh)	468	Resident Elec DS	$ 4,538.61	Total	$ 10,906.55	Residents Total	$ -	Payback	24.67		
Sale Price	$ 0.09	Resident Matter Fees	$ 6,771.60					IRR	-14.37%		
Grid Price	$ 0.22	Resident Total Costs	$ 11,310.21					NPV	$ 5,769.30		
Feed-In Tar	$ 0.08	Resident Levy Per Annum	$ 807.87								
Matter Fee (Monthly)	$ 9.90	OC Common Load	$ 2,771.42								
System Size (kw)	54	OC Matter Fees	$ 118.80								
Daytime Common Usage (kWh)	30832	OC Total Costs	$ 2,890.22								
Daytime Leftover Production (kWh)	50492	Annual Clean	$ 1,080.00								
Cost per kWh	1.32	Annual Inspect	$ 150.00								
DS Install Cost Apartment	1397	Inverter Replace	$ 7,769.18								
Number Panels	216										

Year	0	1	2	3	4	5	6	7	8	9	10	11	12
Energy Price Increases		0%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Owners Corporation Savings	0	$2,739	$2,813	$2,889	$2,967	$3,047	$3,129	$3,213	$3,300	$3,389	$3,481	$3,575	$3,671
Owners Corporation Net Benefit	0	$2,620	$2,694	$2,770	$2,848	$2,928	$3,010	$3,095	$3,181	$3,270	$3,362	$3,456	$3,552
Cumulative Owners Corporation	0	$2,620	$5,314	$8,083	$10,931	$13,859	$16,869	$19,964	$23,145	$26,416	$29,778	$33,234	$36,786
Residential Savings	0	$4,514	$4,636	$4,761	$4,890	$5,022	$5,158	$5,297	$5,440	$5,587	$5,738	$5,893	$6,052
Residential Net Benefit	0	$-	$122	$247	$376	$508	$643	$783	$926	$1,072	$1,223	$1,378	$1,537
Residential Cumulative	0	$-	$122	$369	$745	$1,252	$1,895	$2,678	$3,604	$4,676	$5,899	$7,277	$8,815
Trust Earnings	0	$7,826	$8,037	$8,254	$8,477	$8,706	$8,941	$9,182	$9,430	$9,685	$9,946	$10,215	$10,490
Trust Cumulative	-$120,446	-$112,620	-$104,583	-$96,329	-$87,853	-$79,147	-$70,206	-$61,024	-$51,594	-$41,910	-$39,340	-$29,125	-$18,635

Year	13	14	15	16	17	18	19	20	21	22	23	24	25
Energy Price Increases	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Owners Corporation Savings	$3,770	$3,872	$3,977	$4,084	$4,194	$4,308	$4,424	$4,543	$4,666	$4,792	$4,921	$5,054	$5,191
Owners Corporation Net Benefit	$3,652	$3,753	$3,858	$3,965	$4,076	$4,189	$4,305	$4,425	$4,547	$4,673	$4,803	$4,936	$5,072
Cumulative Owners Corporation	$40,438	$44,191	$48,049	$52,014	$56,090	$60,279	$64,584	$69,008	$73,556	$78,229	$83,032	$87,967	$ 93,039
Residential Savings	$6,215	$6,383	$6,555	$6,732	$6,914	$7,101	$7,292	$7,489	$7,691	$7,899	$8,112	$8,331	$8,556
Residential Net Benefit	$1,701	$1,868	$2,041	$2,218	$2,400	$2,586	$2,778	$2,975	$3,177	$3,385	$3,598	$3,817	$4,042
Residential Cumulative	$10,515	$12,384	$14,425	$16,642	$19,042	$21,628	$24,406	$27,381	$30,558	$33,943	$37,541	$41,358	$ 45,400
Trust Earnings	$10,774	$11,064	$11,363	$11,670	$11,985	$12,309	$12,641	$12,982	$13,333	$13,693	$14,063	$14,442	$14,832
Trust Cumulative	-$7,861	$3,203	$14,567	$26,237	$38,222	$50,531	$63,172	$76,154	$89,487	$103,180	$117,243	$131,685	$ 146,517