Opportunities and obstacle to the uptake of photovoltaics and sustainable technologies in the Christchurch commercial rebuild

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Abstract

Christchurch has been presented with a once-in-a-lifetime opportunity to incorporate renewable energy generation and energy efficient technologies into its buildings as part of the city rebuild. This study looked specifically at the application of photovoltaic (PV) energy generation for commercial buildings in Christchurch, seeking to understand the barriers and opportunities to its uptake. Through a quantitative analysis of the business case for PV on commercial buildings in the CBD, we found that the financial payback for a typical installation is beyond standard commercial investment timeframes. An understanding of real and perceived barriers to uptake was gained through a series of interviews with stakeholders across the spectrum of the commercial property sector – developers, investors, tenants and consultants. An investigation into a number of incentives was undertaken, in order to discover their relevance in overcoming barriers to PV uptake. Drawing from the results of these two approaches we have uncovered widespread adoption of renewable energy and energy efficient technologies in commercial construction, however noting that PV is typically excluded on the basis of cost. Recommendations to encourage greater uptake of these technologies in the Christchurch rebuild are then presented.

Contents

Introduction

Christchurch has endured significant damage to its physical infrastructure from the recent earthquakes, which has left city officials and residents with the task of creatively rebuilding the heart of Christchurch. An important aim during the rebuild process is to create a city of the future; a city at the forefront of green initiatives and their uptake, which encourages the sustainable use of resources.

This report is specifically focused on the sustainable use of energy in Christchurch. The foundation of the report is based on a brief developed by the Christchurch City Council (CCC), to assess the uptake and opportunities to encourage greater photovoltaic (PV) energy generation by Christchurch Commercial Businesses. Research in the field of PV energy uptake and renewable energy use within Christchurch has not been looked at before, making this research both unique and necessary for the purposes of PV and its uptake. Furthermore, this is a prime time to analyse PV energy generation as those who are rebuilding Christchurch and particularly those businesses within CBD have the opportunity to include green initiatives such as PV use as part of their construction processes.

PV is a term encompassing all technologies involved in producing electricity from solar radiation, commonly known as solar panels. PV technologies have become increasingly popular in recent decades due to a combination of improvements in technology, dramatic price decreases, and an increasing interest in sustainable energy sources. A PV system can drastically reduce the electricity charges faced by an organisation. However, the extent of this depends on when the system generates electricity relative to when the organisation consumes electricity, and what their electricity supplier is offering to pay for any surplus generated energy. Electricity generated at the same time as it is consumed will reduce the electricity charges by offsetting the need to purchase electricity, offering the greatest payoff as each unit generated by PV will produce savings equivalent to their prevailing electricity rate. If an organisation generates surplus electricity to what they are using at a given time, then the excess electricity is fed back into the local electricity grid, and is purchased by the electricity supplier at a reduced rate, known as a feed-in tariff. At present in New Zealand, feed-in tariffs are lower than the full tariff; thus PV generated electricity that is fed into the grid instead of offsetting internal electricity consumption will reduce the payback of the PV system. Therefore, to maximise the payback of a PV system, it is important that the system is specified appropriately for an organisation's electricity consumption pattern. Commercial electricity users typically face a tariff regime that varies according to the time of day, reflecting the expense of supplying electricity during periods of peak demand. The payback for PV systems will depend on the prevailing electricity tariff during daylight hours when solar radiation is greatest.

There are a number of current initiatives which aim to encourage the uptake of sustainable resource use mechanisms within Christchurch. The CCC and partners have introduced the Christchurch Energy Grant (CEG) in an attempt to encourage the uptake of renewable energy and advanced energy efficiency measures in the rebuild of the city's CBD. The grant offers up to 30% of the capital cost of qualifying technologies, up to a maximum of $300,000, for commercial buildings located in the Christchurch CBD with a floor area of at least 1000 square meters and a PV system capable of generating in excess of 50,000 kWh per annum, for a simple payback of no more than 8 years (Christchurch City Council, 2013).

The process of determining the current appetite for PV and it's uptake among those involved with the rebuild in the Christchurch CBD was based on two approach methods. A quantitative approach sought to provide an unbiased assessment of payoff periods and total cost of ownership for PV technologies while a qualitative assessment aimed to determine the real and perceived barriers to PV uptake amongst commercial building developers, investors and tenants. The results indicated a poor business case for PV in Christchurch and a relatively weak appetite for PV uptake. However, it was noted that the commercial building sector and stakeholders are well-informed about PV and sustainable technologies, which has driven the uptake of a number of other sustainable technologies attributed to energy efficiency and renewability.

Globally the uptake of PV has been very successful in specific locales, which can be attributed to targeted policies. With a poor uptake of PV in Christchurch to date, CCC and partners can use these international examples to inform policy development with the aim of improving uptake. This report clearly identifies obstacles that have limited uptake of PV locally to date such that these can be specifically targeted so that Christchurch capitalises on this unique opportunity to improve the energy sustainability of the commercial building stock.

Methodology

Quantitative

In order to assess the investment value of a PV system, it was necessary to gain an understanding of the installation costs. A 40kW system was chosen as it was conservatively estimated to meet the requirements of the CEG. Quotes were sought from 16 suppliers for the supply and full installation of PV systems, with four firms replying, giving six different options altogether. Given the modular nature of PV systems, the received quotes were not all for systems of precisely 40kW; thus, the price per watt installed is more appropriate for comparing suppliers than the quoted price, which ranged from $118,000 to $133,000.

Investments can be assessed through a number of methods with varying degrees of complexity, however, in producing a generic business case for PV two relatively simple methods were chosen – payback analysis and net present value (NPV). Payback analysis takes a simple view of the investment, measuring the time taken to recoup the initial investment; however, this does not take into account the cost of capital required to fund the project. This is useful when discussing investments in general terms, as it is agnostic to the different cost of capital faced by organisations. NPV provides a more comprehensive assessment, taking into account the cost of capital, following the principle of the time value of money. For NPV analysis the average cost of capital for listed firms in the NZ property sector was used, 7.0% in 2012 (PwC, 2013).

The investment value of a PV system relies on the modelling of a range of variables, and a number of conservative assumptions were chosen in specifying these. Climatic conditions were based on the NIWA SolarView tool (National Institute of Water and Atmospheric Research, 2013), for the average PV system characteristics (in Table 1, discussion), standard industry mounting procedure (Building Research Association of New Zealand, 2013), and a Christchurch CBD location. It was assumed that all of the electricity generated by the system is consumed within the premises, as the use of electricity in commercial buildings typically matches the generation of solar electricity – during the daytime (Camilleri & Babylon, 2011). This meant that no feed-in tariffs are involved and the financial return of PV was then based on the savings afforded. The savings were from the electricity generated by the panels and the prevailing electricity tariff, based on indicative commercial pricing for 2014 from Meridian Energy, an electricity retailer with a large South Island presence. Commercial electricity varies by time of day and month, and is also subject to local lines charges and Electricity Authority levies, all of which were incorporated into modelling. Reflecting on the expected performance decrease over the life of a PV system, it was assumed that energy output would decrease by 20% over a 25-year lifespan, which is guaranteed by suppliers. The long-term outlook for electricity prices is mixed, however, a 25% rise over 25 years was assumed as the midpoint of several scenarios (Ministry of Business, Innovation and Employment, 2010). All of these variables were combined into a model that calculated the electricity generation and financial value of a PV system per hour for each month of the year. This produced a generalised analysis; specific organisations looking into PV should conduct their own detailed analysis specific to their circumstances. A more detailed commentary about the assumptions made is supplied in Appendix A.

Qualitative

In order to determine the current appetite for PV in the city, the perceived and real barriers to uptake needed to be understood, along with the incentives people felt would allow them greater opportunity to incorporate PV. The best way to determine the answers to these questions was through talking directly to people who are exposed to the solar industry. This included a mixture of architects, construction companies, building services consultants and owners and developers. A questionnaire was designed that would act as the starting point for conversation during the interviews (Appendix B). A list of people and companies was compiled based on their relevant insight into the current PV appetite and market of the city. Before contacting these potential interviewees, the list was sent to Tony Moore (Council contact for the project), to determine if there were any he might add, and to see if he could provide the contact details for any of them – which he did. The next step was contacting the people to see whether they were interested in meeting to answer the questionnaire and have an informal talk about PV. Out of the total of 12 people and businesses contacted, 7 were willing to meet, and the remainder were either unwilling to meet or did not reply. Over the next two weeks, all of the interviews were conducted. All interviews (with the permission of the interviewee) were audio recorded. The final step in collecting this qualitative data was to playback each of the interviews and transfer important findings into legible and practical notes that can be used in combination to find answers to the aforementioned questions.

Discussion

PV as an investment

The installation cost of PV is typically quoted in terms of the price per Watt of installed capacity. Based on the quotations received, this is in the vicinity of $3 per Watt installed, with the spread shown in Table 1, alongside key system parameters. Warranties for PV systems are relatively complicated but fortunately standardised across the industry. Product or workmanship warranties covering panels and inverters cover 5-12 years, and panel performance warranties cover up to 25 years. The pricing for PV was relatively consistent between this small sample of suppliers, suggesting a degree of maturity in the market. However, this is a rapidly evolving technology, therefore this analysis will rapidly loose currency. The benchmark of $3 per Watt of installed PV capacity remains a useful reference point for those seeking quotes for PV. These quotes were all-inclusive and suppliers provided all products and expertise necessary to mount and connect a PV system into the building.

Table 1: - Summary of PV system parameters supplied by four suppliers for a 40kW system

Parameter	**Min**	**Mean**	**Max**
Price per Watt installed	2.95 $/W	3.11 $/W	3.33 $/W
Panel efficiency – *(600W/m2 conditions)*	13%	15%	17%
Inverter efficiency	95%	97%	98%
Length of warranty			
Panel (product)	10 yr	10 yr	12 yr
Panel (90% performance)	10 yr	11 yr	14 yr
Panel (80% performance)	25 yr	25 yr	25 yr
Inverter	5 yr	9 yr	10 yr

Financial modelling of the business case of a PV system to meet the CEG specifications established a weak business case. The simple payback period was found to be approximately 12 years, however the CEG specifies a simple payback of less than 8 years; thus it appears unlikely that a PV solution can completely satisfy the CEG requirements at present. Improvements in PV performance, reductions in PV cost, or electricity tariff increases will likely improve this in the long term. The NPV of the system, analysed over a 25-year period, was calculated to be -$1,128, which suggests that savings in electricity charges over 25 years are approximately equal to the $124,000 installation cost, and debt servicing charges. Such a system would approximately break-even for an organization with a 25-year investment horizon, however few organisations are willing to take such a long-term view. These estimates are based on conservative scenarios, and are all within warrantied parameters, therefore represent a relatively stable long term forecast.

Appetite for PV energy generation in Christchurch's CBD and barriers to uptake

Interviews with a number of industry leaders indicated there is currently only a limited appetite within the business community for PV energy generation in large new buildings in the CBD. The appetite for PV generation appears to be greater amongst small and medium sized developments than compared with larger developments. When conducting interviews with stakeholders involved in the CBD rebuild, a number of recurring themes regarding perceived barriers to greater PV uptake emerged. The following points were the most consistently reported barriers to uptake.

- The cost of PV systems is the primary barrier to greater PV uptake in the CBD.
- The length of the payback period is seen as economically unviable in current market conditions.

The most commonly perceived barrier to PV uptake in the CBD rebuild is the cost of PV systems. The high initial capital investment required when incorporating PV systems as part of a new building, is viewed as economically unviable at this time by the majority of those interviewed. Interviewees indicated that an acceptable payback period for most developers on capital expenditure such as PV, is around three years. Some would stretch that payback period out to five years if a convincing business case was presented to them on the advantages of including PV; however, even five years falls well outside this report's estimated 12 year payback period for large commercial PV installations in Christchurch. As a result, even those with a positive perception of PV usually will not install PV, unless other values outweigh purely economic considerations.

- PV is viewed as a 'luxury' item at a time when other associated costs are rising for developers, owners, and tenants.
- Tenants now prioritize building strength and safety for staff, clients and customers.
- Insurance costs have spiked since the earthquakes.
- Rents have risen (almost doubled) to around the $400 sq/m for new office space in the CBD.

Since the first of the Canterbury earthquakes, in September 2010, developers, owners and tenants have faced resulting cost increases. These costs extend further than simply a disruption of business. Confronted with large cost increases, interviewees stated that PV systems are viewed as a luxury item when planning new buildings; as such they are often amongst the first item to be trimmed from plans. Insurance costs have risen sharply since the earthquakes, while increased construction costs, and high demand for new buildings have driven a rise in rental costs. As safety is the primary concern, a far greater emphasis is now focused on the structural integrity of buildings, rather than investing in perceived luxuries such as PV, with businesses preferring to invest in premises which exceed the building code.

- PV is viewed as a relatively new and unproven technology for commercial buildings; more quantitative data proving its economic benefits is needed.
- Reliability called in question by different warranties for different parts of PV systems.
- Few examples in Christchurch for people to see and get used to the idea of PV energy generation being a viable, mainstream option.

Despite being an established technology in some cities overseas, there remains a perception in Christchurch that it is a somewhat unproven niche, or fringe technology. It is definitely not considered to be a mainstream, economically viable, and reliable energy generation source. The lack of visible examples of commercial PV usage in Christchurch reinforces that view, with several interviewees believing that is a major barrier to uptake; there is a perception that if nobody else utilising PV, then it must not be economically viable here. Reliability is also a concern, and various warranties for different parts of the system (as short as five years) raise the possibility that replacement parts may be required before the system has even paid for itself.

- A widely held belief that New Zealand gets most its energy from renewable sources, so PV may not give any major environmental benefits.
- Owners/developers are already incorporating other green technology so feel they are already 'doing their bit' for sustainability.

As the vast majority of New Zealand's electricity is already generated by renewable resources (such as hydro and wind generation), and not from coal powered plants or other carbon based generators, most interviewees believed there was no real environmental benefit to be gained from utilising PV energy. Many of those interviewed are already incorporating other green technologies which they believe provide economic and environmental benefits for a far lower initial investment. As such they believe they are already doing their share for the environment by exceeding guidelines for their buildings, and therefore cannot justify investing in comparatively expensive PV technology. Thus, even when compared only to other green initiatives, PV is still viewed as a luxury item during the planning process.

- A lack of education/awareness about PV, especially regarding recent improvements, cost reductions.

The general lack of education, and misperceptions around the true costs and benefits of PV systems remains one of the major barriers to commercial PV uptake in Christchurch. Several interviewees stated they had investigated utilising PV systems at some time in the past and concluded that they were not economically viable. However, many were not aware of the current price of PV systems, or how the price and technology had improved in recent years. Architects and developers believed a lack of education regarding the benefits of PV systems was often behind their client's decision to cut PV before other items, when cutting costs from initial designs.

- Advertised grants can be difficult to qualify for and access.

The majority of those interviewed were aware of several grants available for PV from Energy Efficiency and Conservation Authority (EECA) and the CCC. However, a number believed the criteria was too restrictive (especially regarding the size of building), which creates a barrier to uptake from interested parties. Others stated that the process for accessing the grants took too long, and that developer's plans often proceeded at a pace at which the granting bodies could not keep up with; plans had to move forward before grants had been confirmed.

Other green technologies currently utilised in commercial buildings in Christchurch

As part of the interviews, interviewees were asked if they had considered incorporating other green or sustainable technologies into their buildings, either in place of, or in conjunction with, PV. After collating the data it became apparent that most used these green technologies as a stand-alone option, rather than in conjunction with PV. The most popular options for people using green technologies came out to be glazing, and artesian heating and cooling systems, which are said to currently be more mainstream in Christchurch in comparison to PV. Other forms of green technology that were commonly mentioned in the interviews were both daylight harvesting and sun-heat harvesting. People used other forms of green technology because they are seen as more preferable achievable compared with PV. This is potentially because people also see most of the other green technology options as more affordable than PV - therefore making them more appealing as they can achieve 'green' status without spending as much money. A full list of other green technologies currently in place in Christchurch can be found in Appendix C.

Incentives to encourage the uptake of PV and other green technology in Christchurch

An incentive is a benefit or supplementary reward that serves as a tool to motivate and encourage an individual or group to perform an action or behaviour (Oxford University

Press, 2013). There are currently a range of incentives in place in Christchurch to encourage business owners and developers towards creating a more sustainable, or green, not only CBD, but entire city, predominantly through the use of renewable energy sources. A prime example of a current incentive for people to become more sustainable is the CEG. This grant was created by the Christchurch Agency for Energy and is administered on their behalf, by the CCC. The main aim of the grant is to aid business owners and developers with the cost of the technology needed for renewable source energy. Two of the main criteria for the grant are that; the buildings must be of at least 1000sqm and be located within the cities four main avenues. If building owners or developers do meet all the criteria for the grant then they can be covered for up to 30% of their capital costs for the new technology, to a maximum of $300 000. This grant is not only an incentive for people to begin embracing renewable energy initiatives but is also there as an incentive (reward) for those whose energy efficiency measures extend well and truly above the building code minimum standard. (Christchurch City Council, 2013). A secondary major incentive in place in the city is the Target Sustainability project, which offers free consultancy advice to building developers (who meet the criteria) who are interested in producing resource efficient buildings. This is a joint project between the CCC and the EECA. The grant itself entitles those who qualify for up to $5000 worth of free expert energy advice over the time period of 18 months. Despite these incentives being currently available in the city the uptake of PV and other technology did not appear to be as great as it could be. So as part of the research as to the uptake of PV, it was important to ask the interviewees if there were any incentives that might (better) encourage them to install PV and other green technologies. Even though the scope of stakeholders ranged from architects to building developers, the responses were very similar from all. These responses could then be grouped into three main pathways of initiating incentives; council lead cost related and mandatory enforcement, central government lead cost related and mandatory enforcement and education (Figure 1).

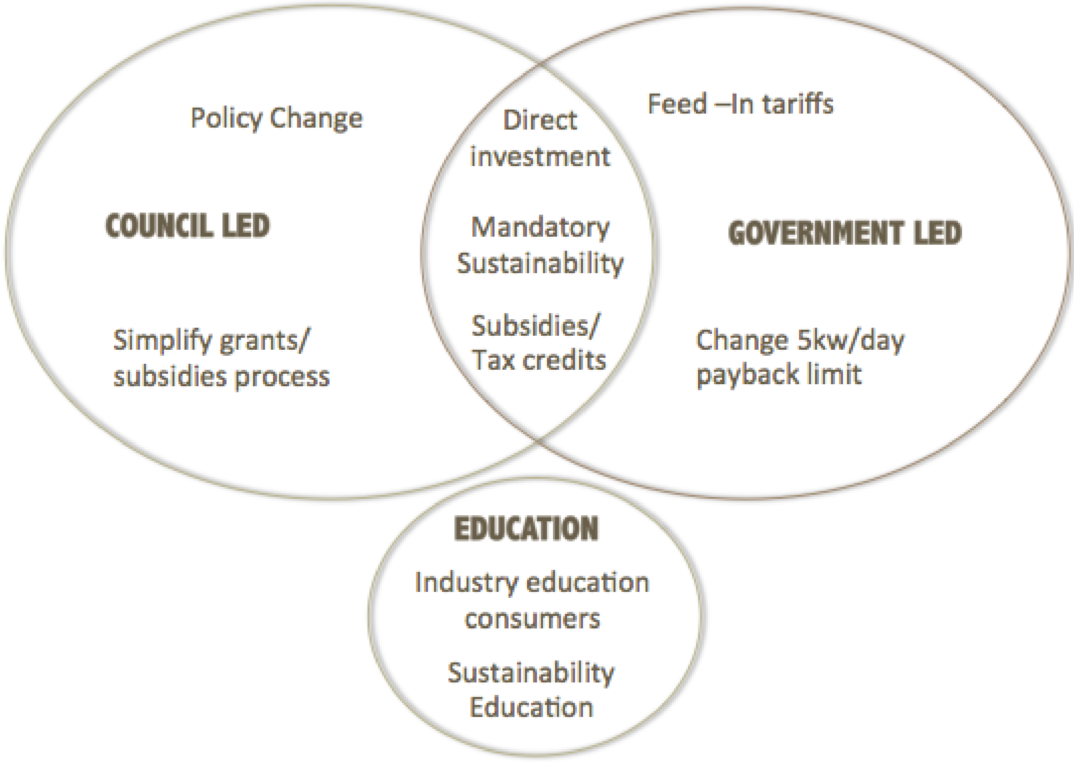

Figure 1: - Venn diagram of options for improving the uptake of PV by the sector responsible.

From the interview data, it was clear that there were many common suggestions of both council led and central government led. Rates rebates, tax credits and mechanisms to lower the payback period were popular suggestions of council lead incentive initiatives – possibly because people see it as easier to instigate things at local level via the council, compared with instigating them at Central Government level. Tax credits have a proven effective track record in increasing the uptake of PV, particularly in the United States where the government will reimburse 30% of the total expenditure for the PV technology and installation. (Timilsina et. al. 2012). Contrary to that, some felt incentives such as rates rebates and grants would do nothing to change the long term behaviour and mindset towards sustainability (which is the ultimate goal), and that they may just create a false market until they are revoked.

Subsequently, the incentive of feed-in tariffs was another popular suggestion. People felt feed-in tariffs would have a much greater (positive) impact on the uptake of PV. This was mentioned as being because they are aimed at a much longer-term contract than subsidies and have reasonable compensation rates, which are tailored case by case accordingly. The present feed-in tariffs paid for surplus renewable energy fed into the local grid are set based on the wholesale cost of electricity, meaning that it is not economic to install PV based on feed-in tariffs alone (White, Lloyd, & Wakes, 2013). This serves as a disincentive for businesses installing large PV systems that contribute to the local grid; instead there is a tendency to specify smaller PV systems that meet only some of a buildings energy use and no more. Feed-in tariffs were possibly such a popular suggestion over here as people are aware of how successful such an incentive can be, as proven by multiple international examples but most notably through Germanys implementation of them as shown by its 44% share of the world's total installed PV capacity (Timilsina et. al. 2012; Couture & Gagnon, 2010)

Lastly, education was mentioned in almost all of the interviews, be it industry organizations, council or central government led education programs on the wider (and up-to-date) information and benefits of sustainability and green technologies. However it is felt that education really on has a place as a complimentary tool to other incentives as it has a much greater chance of not achieving the end result – the uptake of PV and green technologies.

Recommendations

Quantitative and qualitative research has informed the following recommendations to improve the uptake of PV both in Christchurch and nationally:

- Expand the criteria for the Christchurch Energy Grant, to make smaller commercial premises eligible for assistance with their sustainable energy initiatives
- To encourage higher uptake of sustainable energy, feed-in tariffs should be mandated at a national level
- Both central and local government should encourage education around PV and sustainable technologies, in order to build an up to date understanding of these technologies in the commercial sector, and improve perceptions of PV’s value amongst the wider public.

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References

Building Research Association of New Zealand. (2013). Efficiency and effectiveness of solar water heating dependant on collector panels. Retrieved September 12, 2013, from http://www.level.org.nz/energy/water-heating/solar-water-heating/collector-panels/

Camilleri, M., & Babylon, W. M. (2011). *BEES Interim Report Year 4 - Detailed Monitoring* (No. Study Report SR260/2). Judgeford: BRANZ.

Christchurch City Council. (2013). Christchurch Energy Grant. *Target Energy - Target Sustainability*. Retrieved September 10, 2013, from http://www.targetsustainability.co.nz/christchurchenergygrant/

Couture, T., & Gagnon, Y. (2010). An analysis of feed-in tariff remuneration models: Implications for renewable energy investment. *Energy Policy*, *38*(2), 955–965. doi:10.1016/j.enpol.2009.10.047

Ministry of Business, Innovation and Employment. (2010). *New Zealand's Energy Outlook Electricity Insight*. Wellington: Ministry of Business, Innovation and Employment.

National Institute of Water and Atmospheric Research. (2013). SolarView. Retrieved September 10, 2013, from http://www.niwa.co.nz/our-services/online-services/solarview

Orion New Zealand Limited. (2010). *A guide to Orion's pricing*. Christchurch: Orion New Zealand Limited.

Oxford University Press (2013). Definition of incentive in English. *Oxford Dictionaries*. Retrieved from: http://oxforddictionaries.com/definition/english/incentive

PwC. (2013). *The Cost of Capital Report*. PwC.

Saville-Smith, K., & Fraser, R. (2012). *BEES Year 5 - Buildings - Size, Management and Use* (No. BRANZ Study Report 277/1). Judgeford: BRANZ.

Timilsina, G. R., Kurdgelashvili, L., & Narber, P. A. (2012). Solar Energy: Markets, economics and policies. Renewabl and Sustainable Energy Reviews, 16(1), 449-465.

White, L. V., Lloyd, B., & Wakes, S. J. (2013). Are Feed-in Tariffs suitable for promoting solar PV in New Zealand cities? *Energy Policy*, *60*, 167–178. doi:10.1016/j.enpol.2013.04.079

Appendices

Appendix A

Issues of ownership

Developing a specification for a PV system can be a complicated compromise of payoff and time of day factors for an owner-occupied building. However, as most commercial buildings are not owner occupied (Saville-Smith & Fraser, 2012), this introduces an additional complication. Investment in plant such as PV is typically the domain of the building owner, particularly if the payback period is longer than that of the tenant’s lease. However, tenants tend to pay for their own electricity consumption off a separate meter, with the building owner paying for the modest electricity consumption of communal facilities such as lighting and elevators off their own meter (Saville-Smith & Fraser, 2012). For the purposes of this study, we have assumed that the tenant will rent the PV system off the building owner and operate the system to offset their own electricity demand. Any number of alternative commercial arrangements could be followed, however this approach will maximise payback and is the most realistic based on discussions with stakeholders. Many existing installations are on owner-occupied buildings, which negates the need for a commercial arrangement.

Modelling

National Institute of Water and Atmospheric Research (2013) provides a tool to calculate solar irradiance for a specific locality based on local topography and at least 10 years of climate records. The proportion of solar irradiance received by a panel is determined by its tilt relative to the ground and bearing, and the Building Research Association of New Zealand (2013) recommends a North bearing and tilt between 32 and 57 degrees for Christchurch. An estimate of solar radiation was produced from NIWA SolarView for a Christchurch CBD location with a North bearing and 40-degree tilt; this produced an hourly solar irradiance estimate for each month of the year. Electricity generation was then estimated from the hourly and monthly solar irradiance with the average panel and inverter efficiencies of Table 1. Panel efficiency decreases in low solar irradiance conditions, so a lower efficiency figures were used for 0-300W/m2, 300-500W/m2 and >500W/m2. As panel performance is expected to decrease over time, panel efficiency was assumed to diminish by 20% over a 25-year lifespan, reflecting performance warranty periods in Table 1.

Electricity consumption and tariffs

For the purposes of this study, we have used indicative commercial pricing supplied by Meridian Energy, a retailer with a large South Island presence. Electricity prices for large commercial consumers are commercially sensitive and subject to negotiation, thus more representative survey data was unavailable and was unlikely to add further resolution to analysis. Indicative pricing was for the 2014 calendar year, however (Ministry of Business, Innovation and Employment, 2010) forecasts that wholesale electricity prices will rise 20-30% over the next 25 years under a range of scenarios, thus a 25% electricity price rise over this period was incorporated into modelling. Meridian's prices were quoted for four-hour blocks throughout the day, and vary depending on when electricity is consumed – differing between months and weekends or weekdays. Local grid operator Orion Group's additional charges are also sensitive to time of consumption, with tariffs notably higher between 7am and 9pm on weekdays (Orion New Zealand Limited, 2010). The Building Energy End-use Study (BEES) (Camilleri & Babylon, 2011, p. 22) indicates that a commercial building of 1000m2 will consume on average 108,000kWh per annum, with the majority of this consumption during the daytime; therefore it was assumed that 50,000kWh generated by a PV system per annum would be consumed onsite, that is, none would be fed into the grid. Meridian and Orion tariffs were combined with Electricity Authority levies, weighted for a weekend-weekday mix, and multiplied by the estimated hourly PV electricity generation from SolarView to produce estimated yearly revenue from the PV system, which would manifest as a reduction in the organisations electricity charges.

Appendix B.

Interview Questions

- Are you an architect, developer, building owner, and/or tenant?
- Have you investigated utilising photovoltaic (PV) solar panels on buildings in the past, and if so, did you end up having them installed?

- Would you consider incorporating PV panels into future commercial building projects?
- Do you know what installing suitable PV panels for your building would cost?
- Have you calculated how long the payback period would be for PV panels on your building, and if so, how long do you estimate it to be before the PV panels paid for themselves?
- In an economic sense, what do you consider would be an acceptable payback period for you in order to consider installing PV panels?
- Are you aware of the new CCC PV subsidy for commercial buildings in the CBD, and if so, do you know if you qualify for it?
- What do you feel are the main barriers that prevent the uptake of PV energy generation in Christchurch commercial buildings? e.g. initial cost, payback period, owner/tenant costs vs. benefits, reliability, servicing, lack of PV knowledge, regulations etc.
- Have you considered incorporating any other 'green' building or sustainable ideas into any of your projects, such as green roofs, energy saving or water conservation measures etc.?
- Do you believe economic costs are the primary concern when incorporating 'green' ideas into a new building, or do you think businesses consider sustainability to be an important part of being a good corporate citizen, or even an increasingly marketable part of a business' brand?
- Are there any incentives that might better encourage you to install PV or any other green technologies?

Appendix C.

List of other green technologies currently in utilsed in Christchurch

- Solar hot water
- Daylight harvesting
- Sun-heat harvesting
- Glazing
- Artesian heating and cooling
- CO^2 sensors
- VRV (Variable Refrigerant Flow) systems
- Pressurized hot water ring mains systems
- LED lights
- Passive energy designed buildings
- Green roofs/facades
- Rain water harvesting
- Under-floor ventilation
- Tri-generation