Scoping Study

Photovoltaic Power Generation

at Rodney District Council's Head Office,

Orewa

Prepared for

Rodney District Council

By

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September 2010
Final

Executive Summary

This high level study is intended to inform the Rodney District Council (RDC) on photovoltaic (PV) power generation in general, about the potential and practicalities of implementing a system on the roof of the RDC head office building in Centreway Road, Orewa, and on the particular reasons for local authorities such as RDC to take an interest in this type of technology.

PV systems use the most abundant energy source on the planet, solar radiation, to generate electricity. They consume no fuel, generate no greenhouse gas emissions or pollution, are totally silent, and therefore represent the generation technology that is most ideally suited to the urban environment.

The study shows that the roof space available on the Pacific Building of RDC's head offices could support a PV system of up to 100 kWp (kilowatt peak) capacity. At this size, the bulk of the electricity generated would be used 'in-house', requiring little power export, while for the smaller systems considered (5 kWp and 20 kWp) no power export would be required. Electrical interconnection into the building's services would be straightforward; into a close-by distribution board.

When based solely on the avoided cost of electricity the financial payback on investment in PV is still longer than is usually considered commercially attractive, though costs are reducing and rates of return are now approaching bank finance rates. This means that while a system is hard to justify on purely financial grounds the savings in greenhouse emissions and the other advantages outlined below, and discussed more fully in the report, can be gained at low cost to the Council.

The multiple roles of local governments: as decision-makers, planning authorities, managers of municipal infrastructure, permitting authorities as well as educators and role models for citizens and businesses add special value to councils demonstrating renewable energy technology such as PV. By supporting PV demonstration facilities and projects local government can:

- show leadership in promoting renewable generation
- promote local growth and employment opportunities
- assist in growing economies of scale for the industry to reduce costs
- increase energy security and emergency power supply for their own premises
- assist resilience in the local electricity distribution grid
- promote a sustainable image for the region
- provide learning opportunities for council as permitting authority.

While a 100 kWp installation provides the best financial outcome, the installation of a 20 kWp PV system would realise most of the indirect values listed above within a manageable budget and at a low cost over the lifetime of the project. Financial support may be obtainable from an energy industry partner such as Vector, who have supported similar systems, and who may contribute on the basis of the project's value to them.

The installation of a PV system of around 20 kWp is seen as an appropriate sizing for the Rodney District Council to undertake, and it is recommended that the council moves towards implementation. Such a system would cost $120,000, but save a total of around $231,000 in electricity costs over its 30 year lifetime. Some support may be available for such a project.

The Orewa head office building is considered a very suitable location for a demonstration system. This can serve as a learning opportunity and an example to be followed for other council infrastructure in the wider Auckland area and around New Zealand.

Contents

1. Introduction

This high level study is intended to inform the Rodney District Council (RDC) on photovoltaic (PV) power generation in general, on the potential and practicalities of implementing a system on the roof of the RDC head office building in Centreway Road, Orewa, and on the particular reasons for local authorities to take an interest in this type of technology.

PV systems use solar radiation, the most abundant energy source on the planet, to generate electricity. They consume no fuel, generate no greenhouse gas emissions or pollution, are totally silent, and therefore represent the generation technology that is most ideally suited to the urban environment.

PV technology is very much an 'install and forget' type of power generation, requiring virtually no maintenance over its lifetime of greater than 25 years.

PV can be employed in a variety of applications:

Off-grid domestic PV systems:

- Provide electricity to households and villages that are not connected to the utility electricity network (also referred to as the grid)
- Supply electricity for lighting, refrigeration and other low power loads
- Have been installed worldwide
- Are often the most appropriate technology to meet the energy demands of off-grid communities

Off-grid non-domestic PV installations:

- Are used in locations where generation of small amounts of electricity has a high value
- Were the first commercial application for terrestrial PV systems
- Provide power for a wide range of applications, such as telecommunication, water pumping, vaccine refrigeration and navigational aids and signage
- Are commercially cost competitive with other small generating sources

Grid-connected distributed PV systems:

- Provide power to grid-connected customers or directly to the electricity network (normally where that part of the electricity network is configured to supply power to a number of customers rather than to provide a bulk transport function)
- May be on or integrated into the customer's premises, often on the demand side of the electricity meter, on public and commercial buildings, or elsewhere in the built environment

Grid-connected centralized PV systems:

- Perform the functions of centralized power stations
- Supply power that is not associated with a particular electricity customer
- Supply primarily bulk power[1]

An installation on the roof of the RDC head office would fall into the category of a grid connected distributed PV system.

2. Photovoltaic Power Generation

2.1 How it works and types

Solar photovoltaic (PV) power generation uses the "photovoltaic effect" to capture sunlight and convert it directly into electricity. Typically, solar PV cells are made by sandwiching together two thin layers of semiconductor material. Several solar cells together make up a solar panel, and several panels are combined into an array.

[1] http://www.iea-pvps.org/

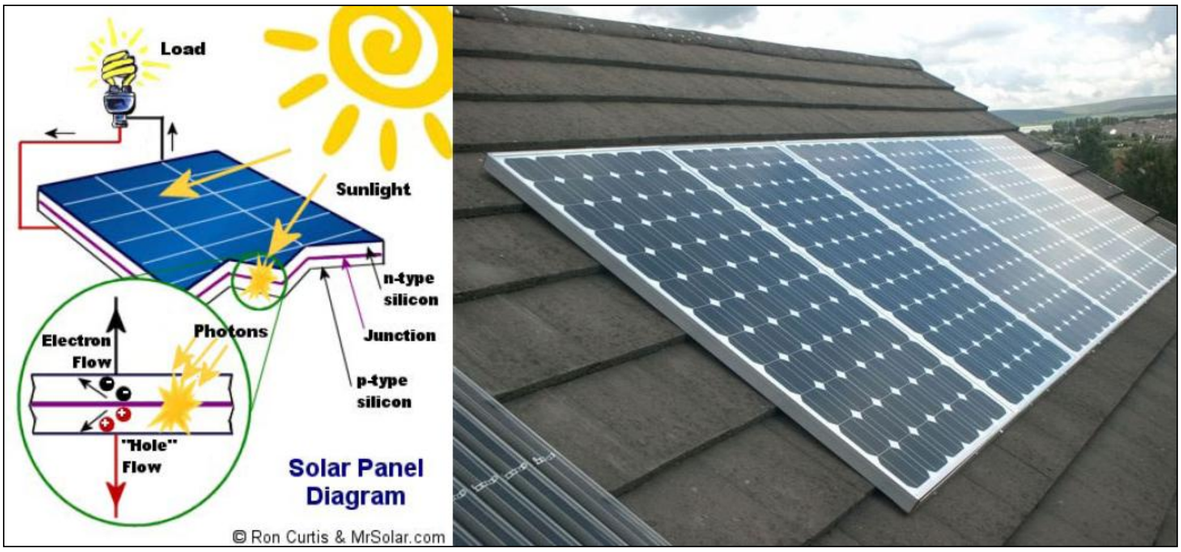

Figure 1: Solar panel diagram and installed on residential roof

In grid connected systems the DC (direct current) power generated by the PV panels is converted to AC (alternating current) power using an inverter, before being fed into the premise or back into the grid through an advanced meter.

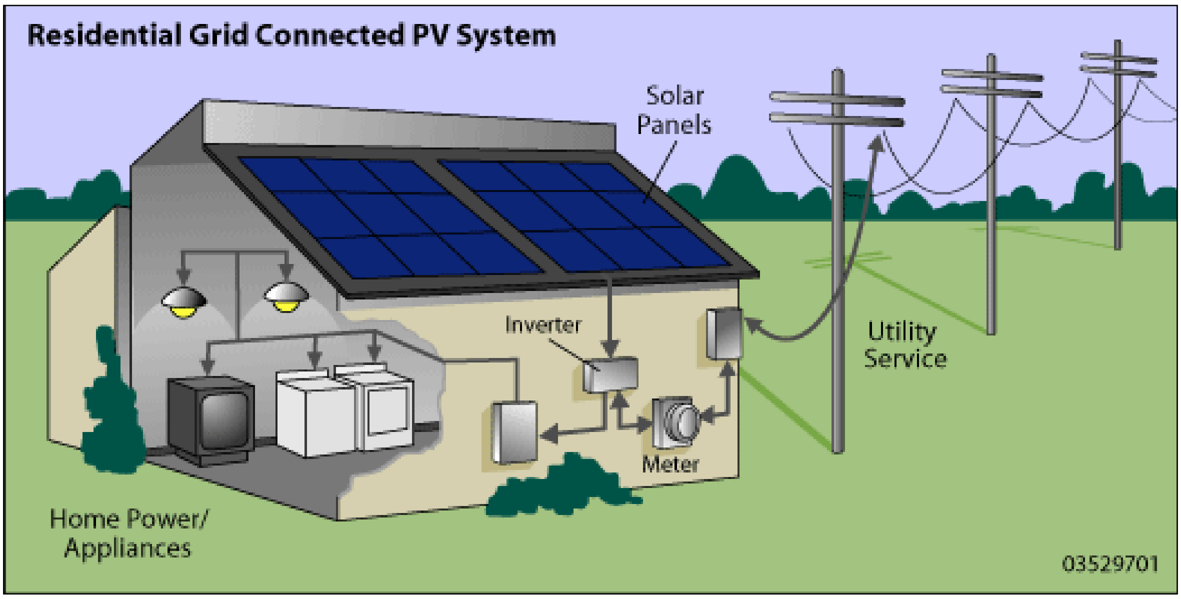

Figure 2: Residential Grid Connected PV system

Today's most common solar PV technology is based on silicon semiconductors and uses manufacturing processes and materials similar to those of the microelectronics industry. Huge investments are being made globally to develop new materials and processes to increase PV cell efficiency (the amount of solar energy converted into electricity per area of semiconductor). The new technologies being developed are lowering costs by using less semiconductor material and streamlining production.

While monocrystalline (or single crystal) and polycrystalline (or multi crystal) cells are still the most common type of solar cells, thin-film technology is gaining an increasing market share. Thin-film cells use very small amounts of semiconductor materials which are applied in thin layers to inexpensive glass, metal and plastic surfaces. Amorphous silicon deposited this way is known as 2nd generation solar cells. At the leading edge of technology are 3rd generation thin film cells, which use more exotic materials than silicon such as cadmium telluride. A more detailed description of types of PV cell technology is given Appendix 1.

In comparison to crystalline cells, thin film cells are less efficient in converting sunlight to energy. They therefore require larger panels and occupy more space for the same peak generation capacity (measured in kWp[2]). This can be an issue where roof space is at a premium. Also, the longevity of thin film cells and performance degradation with age is somewhat less proven than for crystalline cells, in part simply because the technology has not yet been around for long enough. For both technologies manufacturers usually offer warranties for 25 years, with a lifetime expectancy of 30 years and more (excepting some performance degradation).

Inverter technology is also advancing rapidly, with most inverters now incorporating maximum power point tracking (MPPT), to automatically and continuously optimise the electric power output of each array.

The balance of systems is made up of mounting frames and diverse isolator switches and connectors.

There is also considerable investment in the development of tracking systems that optimise the incident sunlight on to the panel throughout the day, mainly for large ground-based utility scale solar farms. Roof mounted systems are installed at a fixed angle and orientation, either mounted flush on a suitably orientated roof, or using a mounting frame to achieve optimum tilt angle and orientation.

2.2 Exponential market growth

Niche markets for PV systems have existed for some time; for powering special applications in remote areas (e.g. telecommunications towers, lighthouses), sometimes in combination with other power sources such as stand-by generators.

However, the major market growth over the past decade has been in grid connected PV applications. These now make up 90% of the world market[3].

The robust and continuous growth experienced in the last ten years is expected to accelerate in coming years. By the end of 2008, the World cumulative PV power installed was approaching 16 GWp[4], and today almost 23 GWp (equivalent in peak output to 23 Huntly power stations as originally built) are installed globally which produce about 25 TWh[4] of electricity on a yearly basis.

Europe is leading the way with almost 16 GWp of installed capacity in 2009 which represented about 70% of the world cumulative PV power installed at the end of 2009, while Japan (2.6 GWp) and the US (1.6 GWp) are following. China makes its entry into the TOP 10 of the world PV markets and is expected to become the major player in the coming years.

The annual market has developed from less than 1 GWp in 2003 to more than 7.2 GWp in 2009 in spite of the difficult financial and economic circumstances, with growth in 2009 another 15%. While Germany reclaimed its leadership, many other markets have started to show significant development. South Korea and, in particular Spain, saw to the contrary their installation figures dropping.[5]

The world PV market has been growing at rates of more than 45% per annum for the past 8 years. Recent forecasts suggest global PV installations will grow to around 22GWp annually by 2013, with Europe and USA being the major growth markets. The European PV Industries Association is forecasting that 12% of Europe's electricity demand in 2020 could be met by PV electricity if grid parity is reached across Europe between 2010 and 2020.

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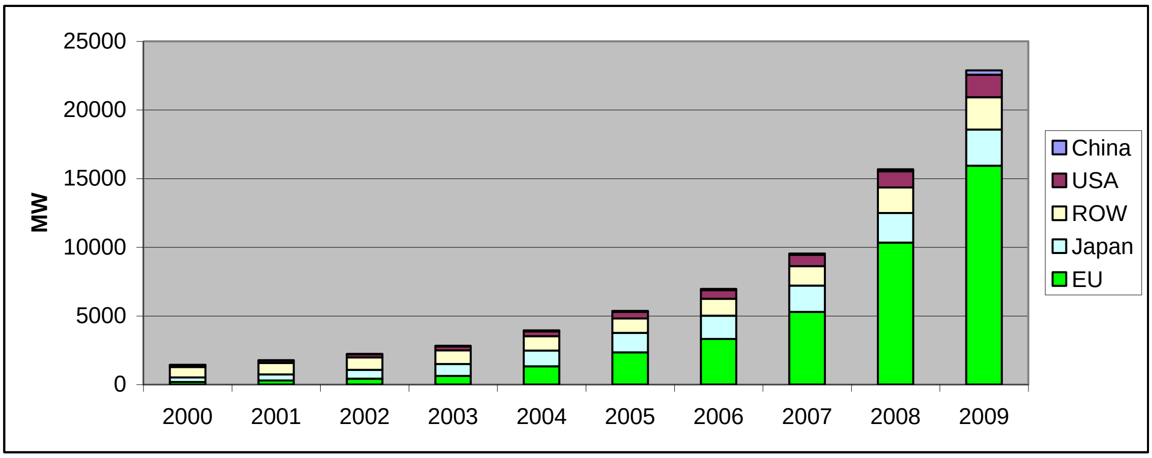
[2] PV power installed is measured in kWp (Kilowatt peak) and refers to the nominal power under Standard Test Conditions STC (1000W/m², 25°C, 1.5 Airmass)

[3] IEA, 2008

[4] 1TWp=1,000GWp=1,000,000MWp=1,000,000,000kWp

[5] Global Markets Outlook for Photovoltaics until 2014, EPIA, May 2010



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
China	19	30	45	55	64	68	80	100	145	305
USA	139	168	212	275	365	479	624	831	1,173	1,650
ROW	763	825	913	1,000	1,044	1,051	1,235	1,422	1,870	2,347
Japan	318	452	637	860	1,132	1,422	1,708	1,919	2,149	2,633
EU	189	286	429	628	1,334	2,341	3,309	5,279	10,338	15,943
Total	1,428	1,762	2,236	2,818	3,939	5,361	6,956	9,550	15,675	22,878

Source: European PV Industry Association (May 2010)

Figure 3: Historical development of World cumulative PV power installed in main geographies

Worldwide production of solar cells is in excess of installations and reached a consolidated figure of 9.34 GWp in 2009, up from 6.85 GWp a year earlier, with thin film production now accounting for 18% of that total.[6]

This massive market growth has largely been driven internationally by government incentives and support, promoting economies of scale and the development of more cost effective technology.

2.3 Cost trends

Compared to other electricity generation technologies, PV technology is unique in its potential for further significant cost reductions since it has no moving mechanical parts. The technology is most closely related to the semiconductor and electronics industry which has been characterised by large improvements in cost efficiency over time.

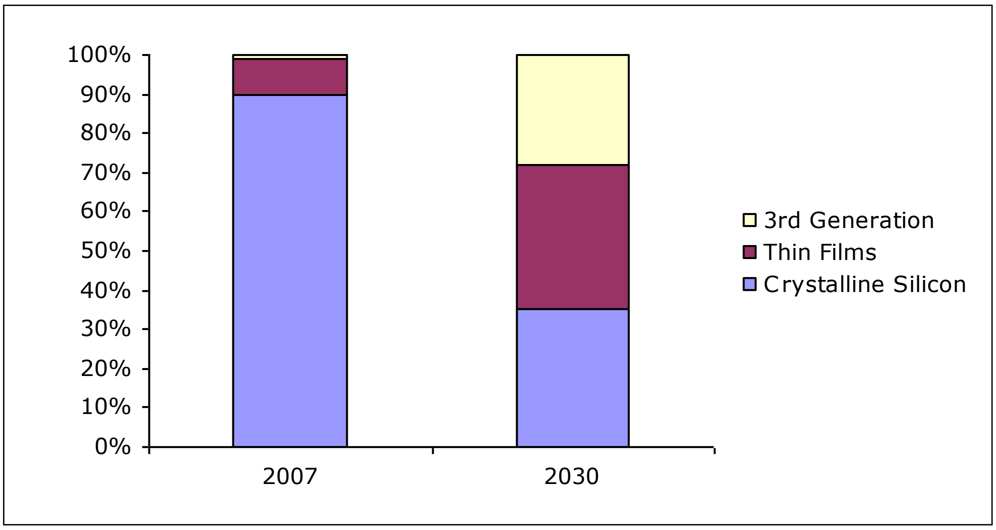


Figure 4: Relative market shares of PV by technology[7]

[6] http://www.commodityonline.com/news/Solar-PV-installations-reach-643-GW-grows-6-26623-3-1.html

[7] Source: Hirshman, 2008; International Energy Agency, 2008

Cost reductions have been, and will further be, driven by economies of scale (forecast to deliver a 20% reduction for every doubling of production capacity), as well as a shift to cheaper and more efficient technologies using less silicon, such as thin-film.

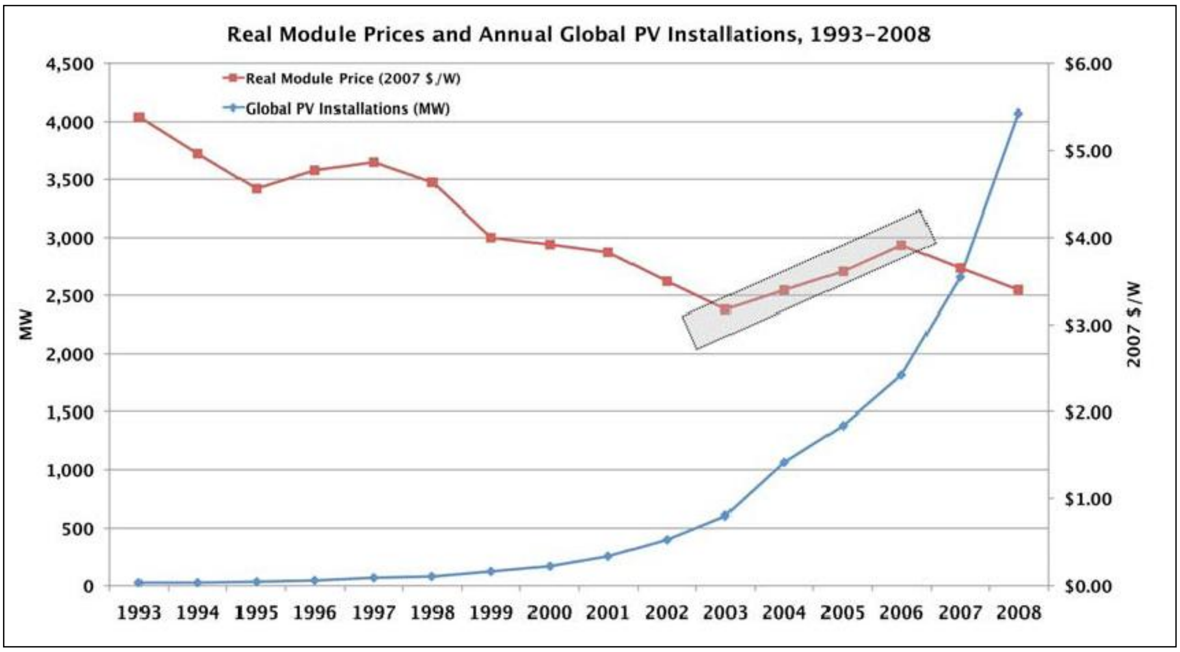


Figure 5: Real PV Module Prices ($US) and Annual Global PV Installations, 1993–2008[8]

PV panel costs are still the most significant component of total systems cost, around 60%. However, panels show the greatest potential for cost reductions going forward, and their share of the total cost is predicted to reduce. Inverter costs (around 12% of total system cost) are also predicted to decline in line with those for other electronics equipment. Mounting frames can account for up to 10% of the total cost (higher for tracking systems), and the balance of costs is made up of minor parts and installation costs. Even though thin film cells are potentially cheaper to manufacture than crystalline cells, their lower conversion efficiencies require larger areas of PV arrays and therefore more material and costs for support structures and cables.

Solar cell production exceeded market demand in recent years, which caused the weighted crystalline silicon module price average for 2009 to "crash" by 38% from the prior year level[9]. This reduction in crystalline silicon prices also had the effect of eroding their percentage premium to thin film factory gate pricing.

Contrary to the trend in panels, production capacity for inverters has recently struggled to keep up with rising demand, causing delivery delays, and not creating the same downward pressure on pricing. The world inverter market for PV is dominated by one manufacturer (SMA in Germany) with a world market share of more then 40%, but many other brands exist worldwide, including Enasolar in Christchurch, which recently developed a 2kW inverter and is planning to offer a range of sizes in the future.

2.4 PV markets and incentives overseas

Growth internationally has largely been driven by support programs for grid connected installations and is highly country specific based primarily on the degree to which PV has been supported by government measures.

Markets have developed most rapidly in countries where strategic and long term market support programs were implemented such as a Feed in Tariffs (FIT) in Germany. Under the FIT, grid access is mandated and PV owners are assured payment for the electricity generated at

[8] Greentech InDetail, PV Technology, Production and Cost, 2009 Forecast:
The Anatomy of a Shakeout, January 2009
[9] http://www.commodityonline.com/news/Solar-PV-installations-reach-643-GW-grows-6-26623-3-1.html

sufficient price levels to make the investment commercially attractive. The FIT is funded from a levy on all power sales rather than from taxes.

Support for PV in Germany was driven by environmental concerns but is now maintained by economics, providing employment for more than 42,000 people. For other countries, reasons such as energy supply security or a more resilient, decentralised power system were more important and other measures such as renewable energy obligations or subsidies in the form of capital grants or tax incentives were implemented.

High dependence on imported fuels, rapid growth in energy use and the need to meet European greenhouse gas emission reduction targets have driven Spain's renewable energy support programmes. In the 5 years since the generous feed-in tariff was introduced, Spain became the second largest PV market in the world.

The initial interest in PV from Japan was from the electronics manufacturing sector which was looking for new products and markets. At the same time, with few local fossil fuel energy resources, Japan has been keen to increase the use of its indigenous renewable energy resources so research and subsequently deployment has been strongly supported by the Government.

The US has been actively involved in PV research for many decades, but its market has been relatively slow to develop overall, although significant markets exist in particular States, such as California, which has deployment programs. These programs have been driven by local energy supply constraints as well as by environmental and economic development goals.

The particular incentive structures put into place in various jurisdictions also influences the structure of the industry and type of industry players. Because of the tax breaks available and renewable energy share targets for many utilities in the United States, the industry there has a stronger emphasis on commercial scale systems built by independent third party developers, under Power Purchase Agreements. In Europe, FIT tariffs incentivised many small home owner owned systems on residential roofs.

2.5 PV market and industry in New Zealand

The existing PV market in New Zealand has largely been built on off-grid sales to rural customers with approximately 4.8 MWp of solar PV having been installed across NZ. Industry surveys[10] indicate that PV is currently being installed at a rate of 420 – 750 kWp per annum.

In 2008, over 110 kWp of grid connected solar PV was installed, which is a significant growth over 2007 and represents 15 - 25% of the PV market. The remainder of the solar PV deployment is mainly small off-grid or fringe-of-grid remote homes with system sizes between 0.5kWp – 2kWp. However, the large growth is taking place in grid connected systems, with private installations of up to 10 kWp and commercial systems larger than this now becoming more common.

Some significant PV installations in New Zealand

The Department of Conservation (DOC) commissioned systems on Tiri Tiri Matangi (7 kWp), Little Barrier Island (3.5 kWp) and Motuihe Island (1.9 kWp) in the Hauraki Gulf, as well as on Mana Island (2.9kWk) and Maud Island (2.6 kWp) close to Wellington. The Department is in the process of installing similar but larger installations on Motutapu and Somes Island. There have also been a number of larger private off grid systems, including a 24 kWp system near Wanaka in the South Island.

Grid connected systems on public buildings were demonstrated successfully by the Genesis Schoolgen programme (15 x 2 kWp systems in stage 2). Larger installations in the commercial sector are situated at Auckland International Airport (51 kWp in 2 stages), and on the roof top of Hubbards finished goods house in Manukau. At 20 kWp this installation is the largest thin-film (2nd generation) installation in New Zealand, and is predicted to produce 29,000 kWh of power per year from 227.5 square meters of panels. The output of this installation is publicly displayed on a screen in the foyer and can also be monitored on the internet on http://www.sunnyportal.com/Templates/PublicPageOverview.aspx?plant=731068a5-f622-4168-b5ae-b0845be107f6&splang=en-US.

[10] Sustainable Electricity Association of New Zealand (SEANZ)

In the past PV panel supply in New Zealand has been through a local wholesaler who purchases from an Australasian distributor, but there are now a number of local distributors purchasing directly from overseas manufacturers, resulting in more competitive PV panel pricing.

At least 15 PV brands are available in reasonable quantity, as well as a range of inverters, controllers and batteries. There is currently limited local manufacture, with a locally developed inverter becoming available only recently. With the major cost item (panels) being imported, this makes system prices very vulnerable to exchange rate changes. There is a range of research and development work underway which could result in New Zealand product being manufactured in the medium to long term.

New Zealand companies involved in the PV sector are generally small and diverse with the majority working in the implementation or supply of imported products. Over 100 organisations currently have reasonable activity in the photovoltaic industry, with around 225 people employed[11].

2.6 Regulatory environment in New Zealand

No special incentives to promote the uptake of PV technology exist in New Zealand, such as subsidies, tax brakes or a FIT. A number of lobby groups have been formed (e.g. REFIT) which are trying to promote the introduction of a FIT. However, NZ has different issues to address in the electricity market compared to most countries overseas. The main issues are transmission and generation capacity constraints in cold winter evenings, and energy constraints in dry winters. PV can contribute little to alleviate the first issue, however it can contribute to the alleviation of energy shortages.

The connection of distributed generation systems such as PV to an electricity network is regulated by the Electricity Governance (Connection of Distributed Generation) Regulations 2007. These regulations determine the process that lines (distribution) companies have to follow to connect a power generator. The process is relatively simple for systems under 10 kW, but somewhat more involved for generators larger than 10 kW, which may require the assessment of required network upgrades, the cost of which may have to be borne by the generator. Most lines companies have published guidelines for connecting distributed generation on their websites (e.g. http://www.vector.co.nz/electricity/distributed-generation).

The Regulations also stipulate that the power imported from the network must be metered and recorded separately from the power exported (injected into) the network. This effectively prevents a practice that is very common overseas, called net-metering, essentially letting the meter run backwards. Net metering effectively forces the power supplier to reimburse exported electricity at the same rate that it sells electricity at, as only the monthly net total is known.

Since no regulations exist in New Zealand for special payment for PV generated power, it is up to individual retailers to decide on the rate they are prepared to pay for any exported electricity. A number of retailers openly or candidly will agree to buy export electricity at the same rate at which the customer purchases electricity, but are not prepared to enter into a long term contract for this. This is a major obstacle for developers of commercial systems looking for bank finance. Where the power generated on site never exceeds the site load, i.e. electricity is never exported, income for export electricity is not relevant, and cost savings accrue at the rate for the avoided electricity import costs.

2.7 Energy yield for grid connected PV arrays in New Zealand

The solar resource is relatively low in intensity and by nature intermittent in availability. Peak energy availability is during the middle of the day, when maximum solar radiation falls on the plane of the PV array.

Yield is greatest during the summer months and, depending on the tilt angle of the panels, summer month yields are typically about double those for winter months. A photovoltaic system does not need bright sunlight in order to operate. It can also generate electricity on cloudy days. Due to the reflection of sunlight, slightly cloudy days can even result in higher energy yields than days with a completely cloudless sky.

[11] Assessment of the Future Costs and Performance of Solar Photovoltaic Technologies in New Zealand, New Zealand Ministry of Economic Development, April 2009

Figure 6 shows the expected annual specific energy yield of grid connected PV arrays in four centres in New Zealand. As expected, the sites further north closer to the equator generally produce a higher yield. However local conditions such as annual sunshine hours (or inversely average cloud cover) also have a significant effect, which explains the relatively high yield in Nelson. Actual yield for any given year will vary as a result of the variability of solar radiation.[12]

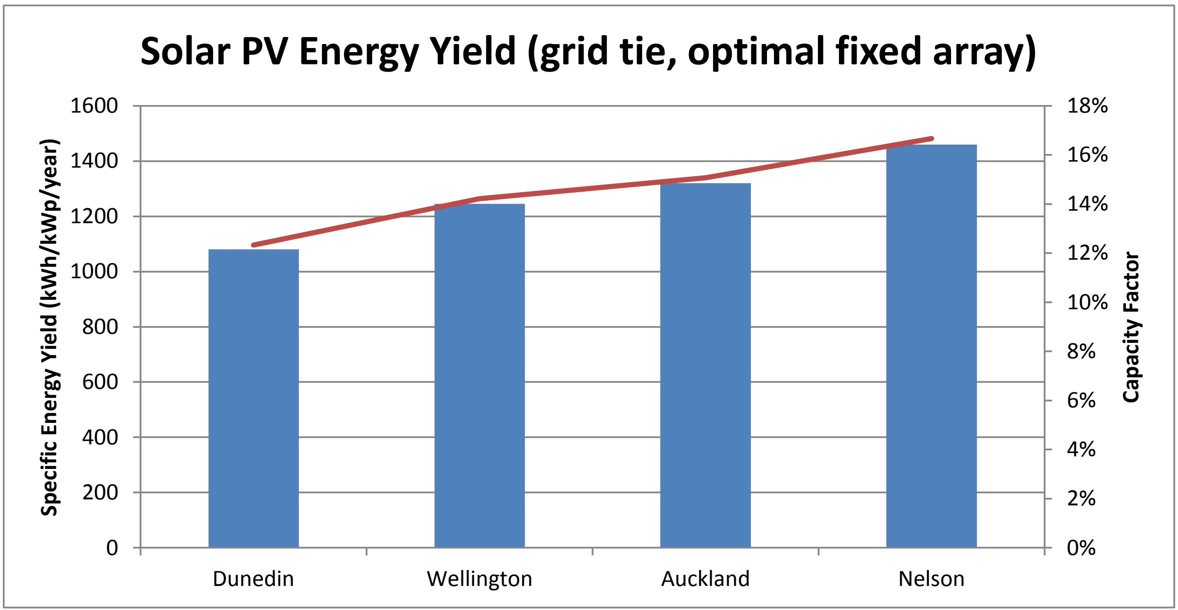


Figure 6: Expected annual specific energy yield for fixed grid connected PV arrays in New Zealand

The ideal yield shown above may, in practice, be reduced by a number of factors:

- less than ideal orientation of the panels (slightly west to geographical north is generally considered best)
- the tilt angle of the panels (often location latitude is quoted as the ideal tilt angle, but for maximum annual yield the angle should be less then this to make more use of the stronger summer sun and longer days; for off-grid systems the tilt angle is often set higher to increase winter yield)
- shading of panels (even partial shading of a module or array can dramatically reduce the performance of the whole array)
- soiling of panels (generally in New Zealand rainfall is sufficient to take care of this as long as the tilt angle is more than 10^{o})
- age of panels (panel performance decreases with age, by about 0.5% per year)
- temperature and type of panels (the cooler the better, but thin film is said to be less susceptible)
- inverter and cabling losses (often around 10%, but less than 5% for a good system)

Even though thin film modules are less efficient and therefore require a larger area per peak capacity (kWp) than crystalline panels, thin film panels are reported to lose less performance in comparison to crystalline panels when heating up in the sun, and under diffuse light conditions (cloudy skies) which are common in New Zealand. It is claimed thin film panels therefore should generate more energy per capacity (kWp) installed than crystalline.

[12] Assessment of the Future Costs and Performance of Solar Photovoltaic Technologies in New Zealand, New Zealand Ministry of Economic Development, April 2009
Assumptions: Orientation – north; Inclination – (37°, 33°, 33°, 30°); Inverter – SMA 6000TL with 97% efficiency Average module performance based on a range of poly, mono and a-Si modules; expected variation of +/- 5% due to module factors such as technology, power mismatch; Wiring losses – 3%; no soiling losses assumed

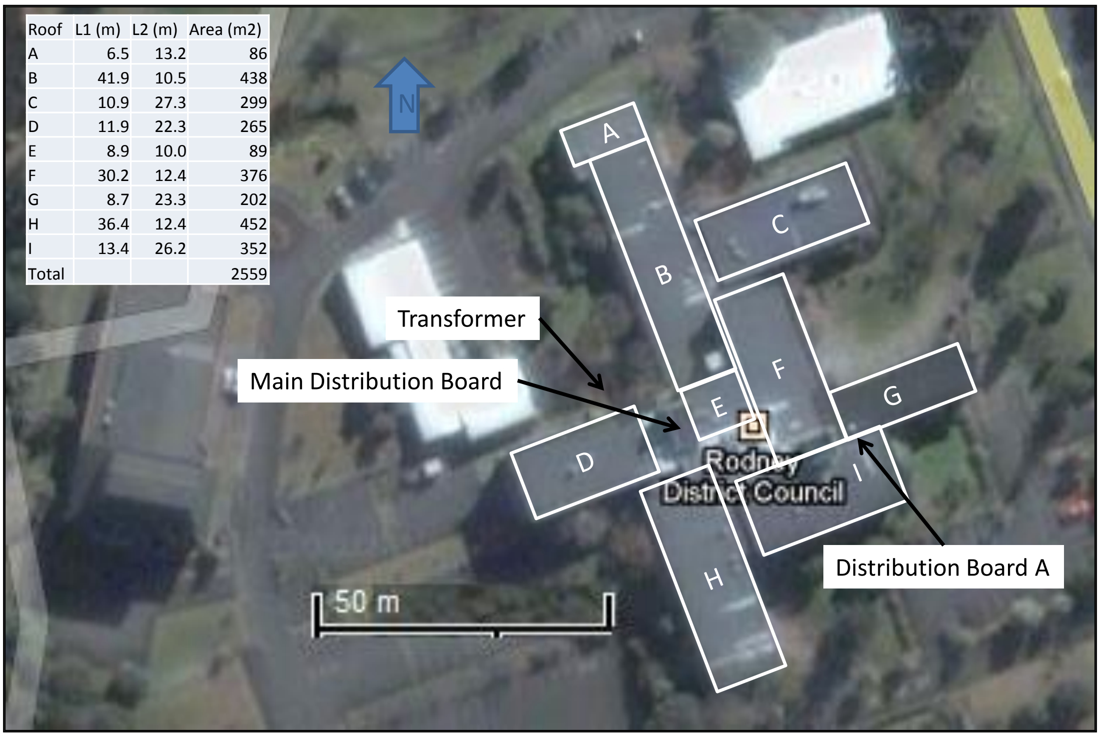
3. Rodney District Council Head Office, Orewa

3.1 Building and roof area

The RDC head office is located in 50 Centreway Road, Orewa, and consists of two interconnected buildings; the Pacific Building, and the more recent Tasman Building. For this study the Pacific Building only is considered.

The Pacific Building consists of multiple wings of differing heights, all with flat roofs. Roofing material is long-run coloursteel with trough section type profile (standing seam) for all wings. Photographs of all roofs are shown in Appendix 2. A plan view of the Pacific Building and approximate roof areas for various roof sections are shown in Figure 8 below. The building alignment is orientated approximately at 340° and 160° from north.

Figure 7: View of RDC head office from the east (main entrance)



Roof	L1 (m)	L2 (m)	Area (m2)
A	6.5	13.2	86
B	41.9	10.5	438
C	10.9	27.3	299
D	11.9	22.3	265
E	8.9	10.0	89
F	30.2	12.4	376
G	8.7	23.3	202
H	36.4	12.4	452
I	13.4	26.2	352
Total			2559

Figure 8: Approximate roof areas of Pacific Building only (does not show Tasman Building, white roof areas are temporary premises no longer existing) and location of some electricity supply infrastructure

3.2 Electricity infrastructure

The RDC buildings on site are all supplied at 415V by a 750kVA transformer. The Pacific Building is fed through the revenue meter on the main distribution board on the ground floor located between roof areas D and E in Figure 8. The main board feeds 4 distribution boards throughout the building.

One of the distribution boards is of special interest because of its location close to roofs G, F and I (identified in Figure 8 as distribution board A). This board is located in a storage room located behind the reception area. It is protected by a 160 Amp circuit breaker, and suitable wall space exists around it on a solid concrete block wall to mount inverters next to it.

Another distribution board (for air-conditioning) is located in the air-conditioning enclosure on the roof straight above the main distribution board. It is protected by a 60 Amp and a 100 Amp circuit breaker, and provides convenient interconnection points for power from roof areas B, E, D and H.

Currently emergency power to the council is provided by a 150 kVA diesel generator. In case of a power outage, a network of intelligent circuit breakers are controlled to achieve load shedding while the generator is operating, with supply to the IT department being prioritized. Emergency lighting is implemented with a large number of dispersed individual battery units. No central battery bank for emergency power exists.

3.3 Electricity loads

The RDC offices use electricity for all space heating (resistance heating or reverse cycle heat pump), water heating (distributed domestic type hot water cylinders), air conditioning, lighting and general power (mainly computer equipment).

The total monthly electricity usage is only moderately seasonal, with summer air conditioning loads during summer days not quite matching the higher heating loads during winter mornings.

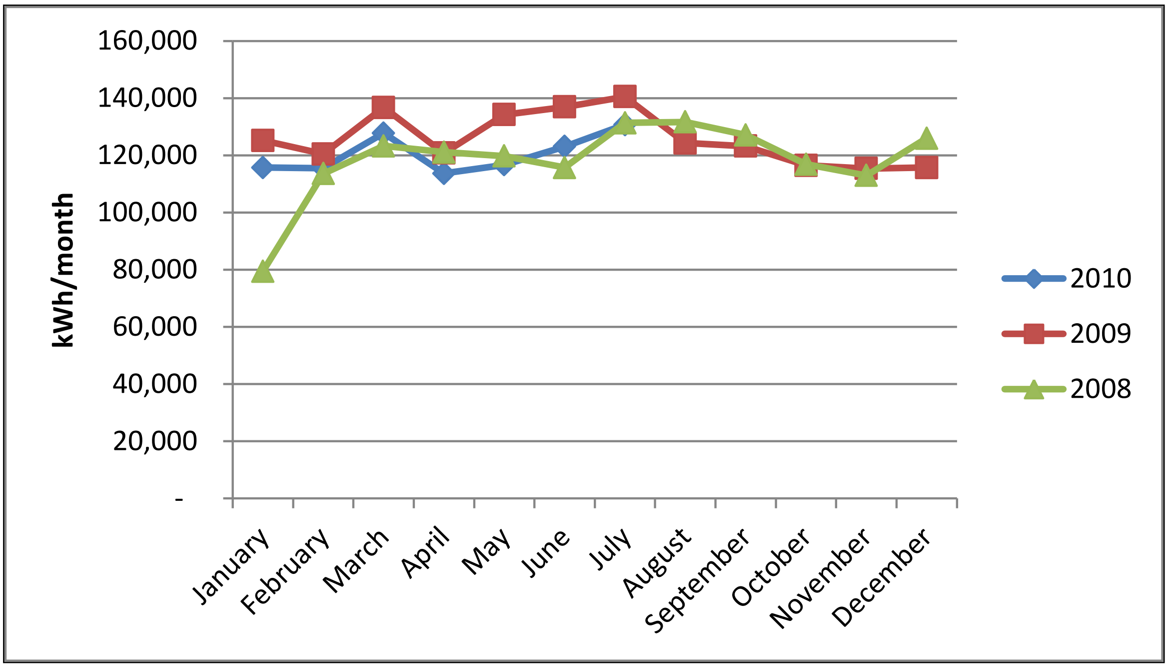


Figure 9: Monthly electricity usage for RDC offices in Centreway Road

3.4 Electricity tariffs and price path

The offices are supplied under a Time of Use tariff which applies varying rates for different 4 hour periods during the day, these rates varying between weekdays and weekends.

Additional to these contract rates are losses that are applied to the metered consumption, Electricity Commission Levies and variable network charges. Figure 10 shows the current total variable charges.

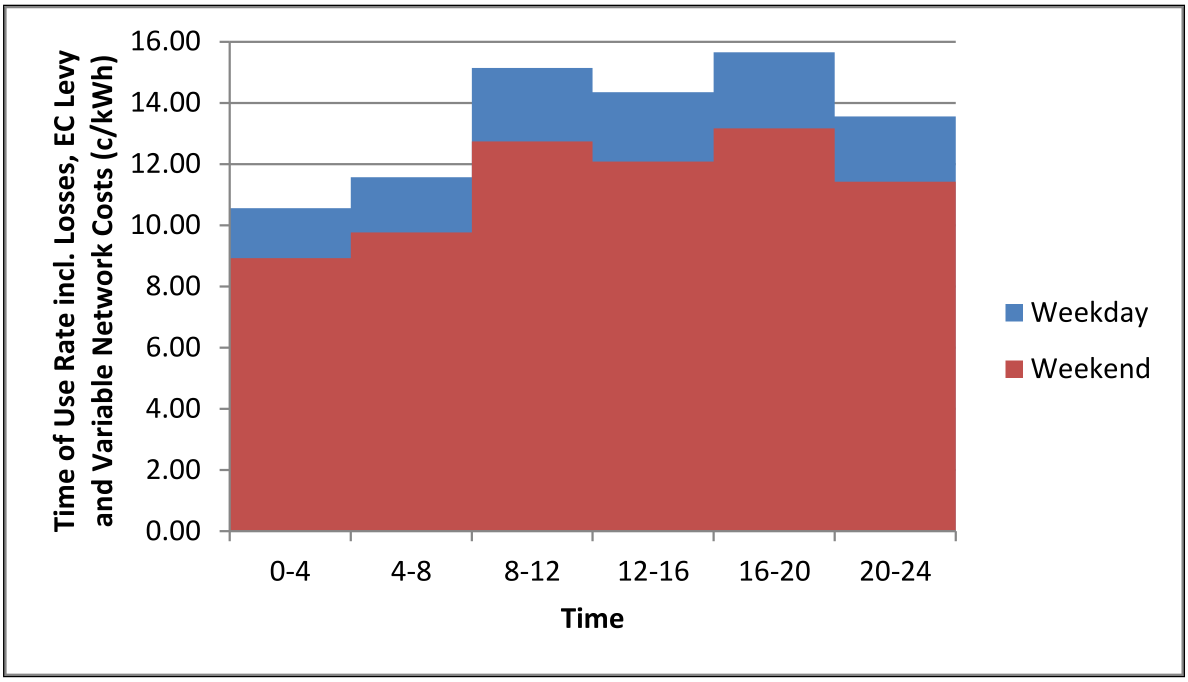


Figure 10: Time of Use Rates

On top of variable charges, network charges also include fixed charges per day, capacity charges and charges based on maximum demand each month at $19.22 c/kVA/day.

4. Photovoltaic power at the RDC head office

4.1 Sizes considered, location and power generated

As all roof areas are flat with only minimal pitch for water run-off, roof orientation is less relevant. However, because the building outlines are orientated around 340°, which is close to ideal for maximum solar yield, panels should be orientated in line with building lines towards 340°, i.e. 20° west of north. No roof shading from neighbouring buildings or high trees applies.

Because of the differing heights of various building wings and because of higher structures on some roofs such as air conditioning condensers and enclosures, shading of some roof sections occurs and needs to be considered for the siting of PV panels. Also, panel rows mounted on a frame for optimum tilt require clear space in between the rows to avoid shading. Table 1 details what capacity PV systems could be installed on different roof areas together with the anticipated power generated per year using a typical yield number.

Roof	Area (m2)	Clear and unshaded	Peak Capacity (kWp)	Energy (kWh/an)
A	86	90%	4.51	5,860
B	438	85%	21.80	28,338
C	299	80%	14.00	18,196
D	265	90%	13.97	18,161
E	89	50%	2.61	3,387
F	376	50%	10.99	14,281
G	202	60%	7.09	9,212
H	452	90%	23.81	30,953
I	352	50%	10.29	13,373
Total	2,559		109.05	141,760
Assumptions:				
Percentage panel area to roof area			45%	
Peak Capacity per panel area			0.130	kWp/m2
Annual Generation			1,300	kWh/kWp

Table 1: PV generation capacity and power yield

For the purposes of this study three system sizes were considered:

1. A 5 kWp system which would fit onto Roof G on top of the main entrance and reception area. This location would give the system maximum exposure to the visiting public. A system this size would represent an example for a large residential type system, probably fitting the widest interest group.

2. A 20 kWp system which could be mounted on a combination of roofs G, I and H. While giving very good exposure to the visiting public, these locations also provide good exposure to passing traffic on Centreway Road.

For both these options the systems could be connected electrically into distribution board A with short and simple cable runs, and with inverters mounted right next to the board onto the concrete block wall.

3. A 100 kWp system would come close to utilizing the full potential of the roof space available. A system this size most likely would be connected into the main transformer.

For any option public exposure and the educational value of a PV installation would further be enhanced by showing a screen in the reception area displaying current PC power generation, generation statistics and other system information. This has been installed at Hubbards, and is common practice for many public installations.

4.2 Power generation profile and comparison to site load

Figure 11 depicts cumulative solar energy levels for a range of days throughout the year at Centreway Road, Orewa, based on NIWA data[13]. This is used to generate typical daily profiles for summer and winter days. These profiles are compared below to typical summer and winter loads for the RDC buildings.

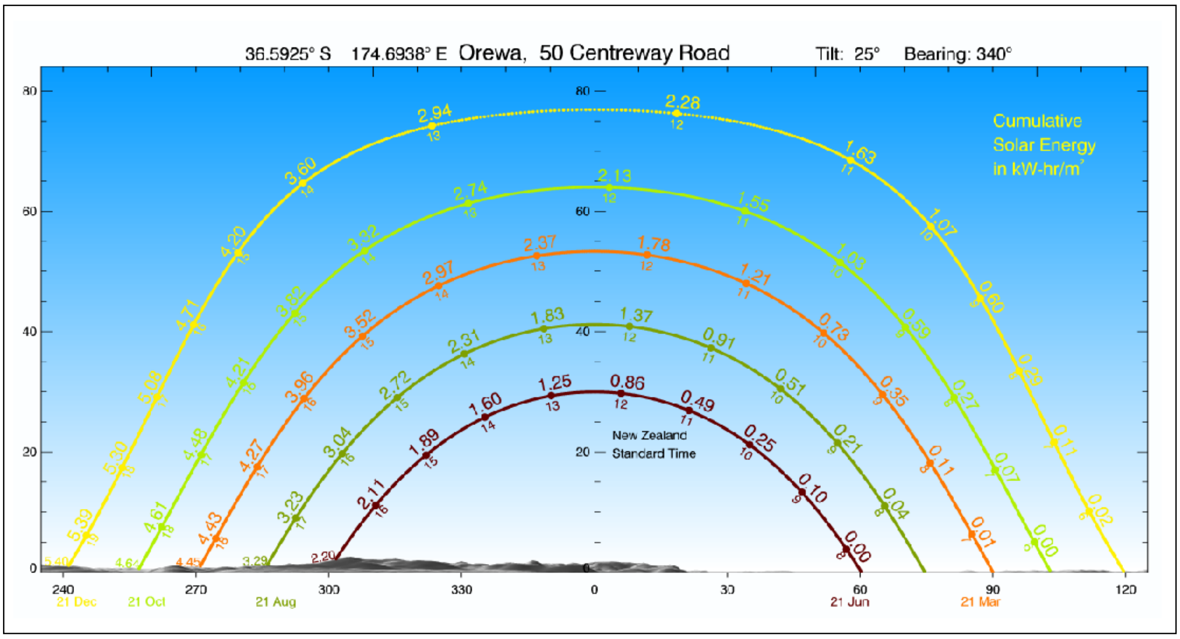


Figure 11: Cummulative Solar Energy in Centreway Road, Orewa

These generation load profiles show the maximum power generated during clear days. In practice, overcast skies and even passing cloud will mean real output will generally stay below the lines indicated in Figures 12 and 13 below, which also show the relation to the electrical load at the site.

[13] http://solarview.niwa.co.nz/

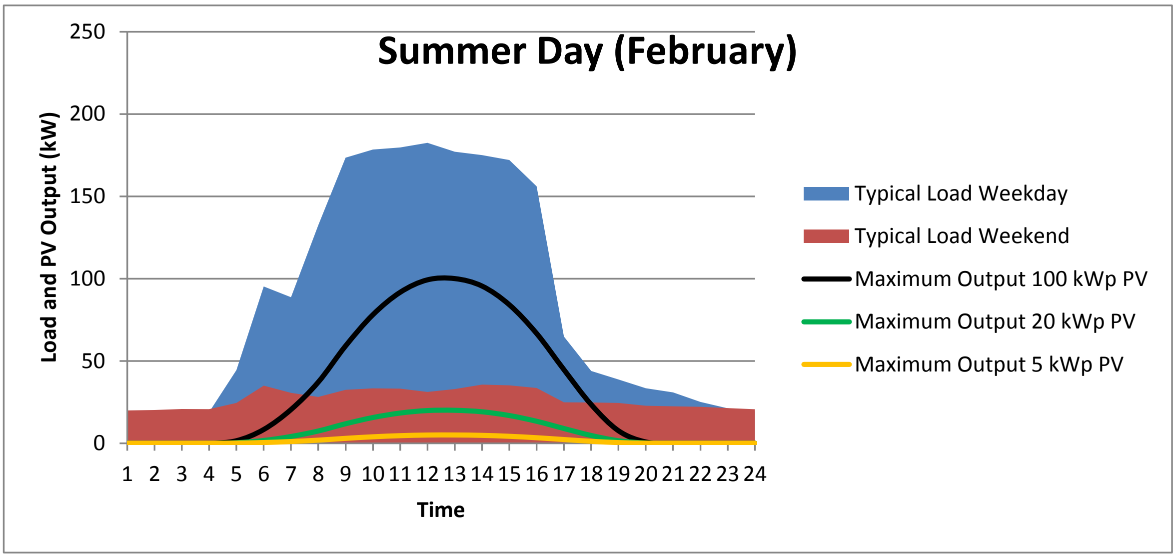


Figure 12: Summer day loads and PV generation

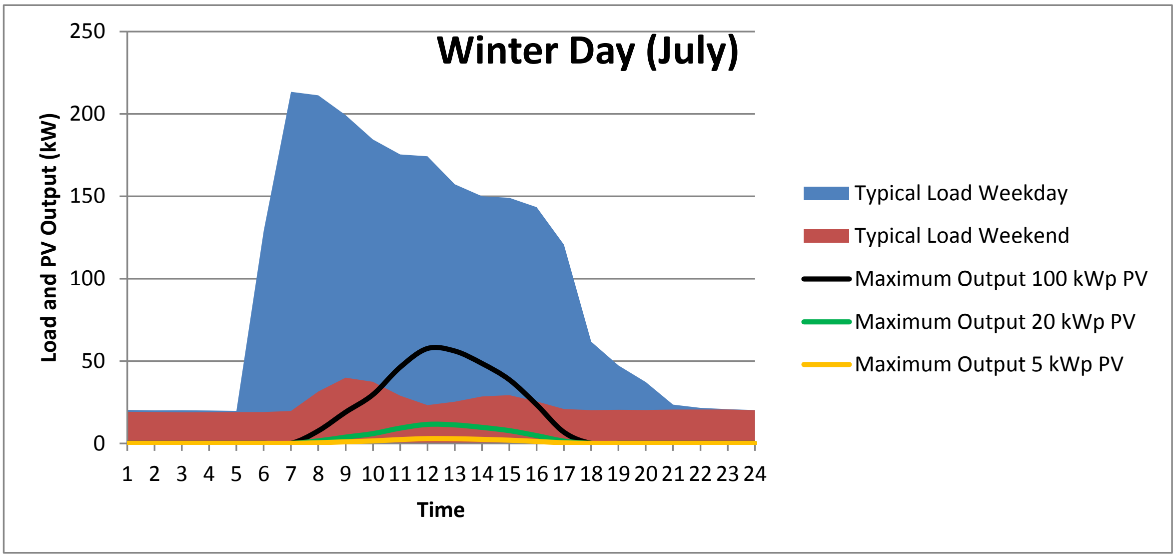


Figure 13: Winter day loads and PV generation

As the maximum generation profiles for the 5 kWp and 20 kWp systems (and up to around 30 kWp) stay below the typical building loads at all times, even during weekends, very little export would be required and the maximum benefit is obtained for all power generated. Even the 100 kWp system would only export power during winter and summer weekend days, and possibly at some low load summer weekdays.

This means that power sales contracts with energy retailers are not a major issue, and that the cost savings achievable with PV can be based on avoided electricity purchase costs.

4.3 Saving in greenhouse gas emissions

Numbers published by the Ministry of Economic Development for the purpose of voluntary greenhouse gas reporting quote an average emissions number for electric power consumed in New Zealand of 174.5 grCO_2equiv./kWh[14]. This number is derived by dividing all emissions from power generation by the amount of all power consumed, i.e. it is an average for all forms of power generation employed, including non-emitting generation such as hydro.

More relevant in calculating the emission savings resulting from PV generation are the emissions that can be avoided from the power station 'at the margin', i.e. the type of generation that has been displaced by PV at any time. This can vary from around 900 grCO_2equiv./kWh if coal fired generation is avoided, to zero emission savings if more PV generation causes water to be spilled

[14] New Zealand Energy Greenhouse Gas Emissions, 2009 Calendar Year Edition, Ministry of Economic Development, 2010

from hydrodams. The relevant data is not published, and emission savings will vary substantially from year to year depending on the mix of stations running 'at the margin'. For the purposes of this study a number of 600 grCO_2equiv./kWh is used, which is deemed to be representative of a typical year where gas and coal fired power stations are regularly the marginal generators.

The table below lists the amount of carbon saved for the three PV systems evaluated, and the value of the saving using a carbon price of \$25/tCO_2equiv.

Option (kWp)	kWh/an generated	tCO2 equiv.	Value per year
5	6,500	3.90	\$ 98
20	26,000	15.60	\$ 390
100	130,000	78.00	\$ 1,950

Table 2: Carbon dioxide emission savings

4.4 Other benefits/standby generation

There is some interest internationally in the addition of small amounts of battery storage to grid systems, to allow independent operation of the system in the event of grid outage. This is of particular interest in areas which experience frequent grid outages or brown-outs. At present, most utilities require the PV inverter to shut down if the grid fails. However, if the inverter is capable of operating in stand-alone mode, it is possible to manually switch over to this mode until the grid supply is restored.

For PV to contribute to emergency power for the council building, it would have to be capable of interacting with the diesel emergency generator load control system. In this case it would be able to supply emergency power even in the 'disaster scenario' of prolonged power outages including interruption of diesel supply. Since no central battery bank for uninterrupted power supply exists, the use of PV as a reliable emergency power supply on its own would come at a substantial additional cost for a central battery bank.

4.5 Value of power generated

Since no power will need to be exported for the two smaller options and only a small part of the power for the 100 kWp option, power sales contracts with energy retailers are not an issue, and the cost savings achievable with PV can be based on the avoided electricity purchase costs.

When the typical generation profiles derived above are applied to the RDC's time of use rates, the current weighted average avoided cost comes to 14.01 c/kWh.

PV also has the potential to reduce demand charges, even though these savings are harder to quantify, because they depend on coincidences of highest demand and PV output at these times. Typically during winter, peak loads occur very early in the day, when PV is not producing substantial output, and very little reduction in maximum demand can be expected.

During summer the daily demand peaks are driven by high air conditioning loads mid day and in the afternoon, exactly at the times (and days) when PV should generate close to maximum output. If conservatively a site demand reduction of 50% of the PV peak capacity is assumed for 4 months of the year, this provides additional cost savings of \$59, \$234 and \$1,172/an for the 5, 20 and 100 kWp systems respectively (equivalent to 0.90 c/kWh generated).

4.6 System costs and energy yield quoted

Cost estimates were obtained from two PV system suppliers in New Zealand, with one supplier providing quotes for thin film as well as crystalline panels. Table 3 lists quoted costs, as well as system and performance details.

More details of the systems quoted are given in Appendices 3 and 4.

Nominal Peak Capacity	5 kWp	17 kWp	20 kWp	100 kWp
Supplier 1 Thinfilm	Modules: Sharp 115W			
No of Modules	45		180	900
Inverter	1*SMC5000		3*SMC7000HV	9*SMC11000TL
System sized in quote (kWp)	5.18		20.70	103.50
Capital Cost (excl. GST)	$ 40,883		$ 134,777	$ 650,250
Est. Annual Yield (kWh/year)	7,020		28,080	140,400
Est. Annual Yield per kWhp	1,357		1,357	1,357
$/kWp	$ 7,900		$ 6,511	$ 6,283
$/kWh/year	$ 5.82		$ 4.80	$ 4.63
Supplier 1 Crystalline	Modules: Sharp 167W			
No of Modules	30		120	630
Inverter	1*SB5000TL		3 * SMC6000	9*SMC11000TL
System sized in quote (kWp)	5.01		20.04	105.21
Capital Cost (excl. GST)	$ 36,125		$ 123,720	$ 593,750
Est. Annual Yield (kWh/year)	6,610		26,440	138,810
Est. Annual Yield per kWhp	1,319		1,319	1,319
$/kWp	$ 7,211		$ 6,174	$ 5,643
$/kWh/year	$ 5.47		$ 4.68	$ 4.28
Supplier 2 Crystalline	Modules: Jingo 180W			
No of Modules	28	98	112	552
Inverter	1 * SMA10000TL	1*SMA17000TL	2*SMA10000TL	6*SMA17000TL
System sized in quote (kWp)	5.04	17.64	20.16	99.36
Capital Cost (excl. GST)	$ 40,565	$ 106,765	$ 123,400	$ 576,780
Est. Annual Yield (kWh/year)*	7,205	25,478	28,926	144,435
Est. Annual Yield per kWhp*	1,430	1,444	1,435	1,454
$/kWp	$ 8,049	$ 6,052	$ 6,121	$ 5,805
$/kWh/year*	$ 5.63	$ 4.19	$ 4.27	$ 3.99

* Manufacturer prediction, deemed to be optimistic

Table 3: Summary of PV system quotations

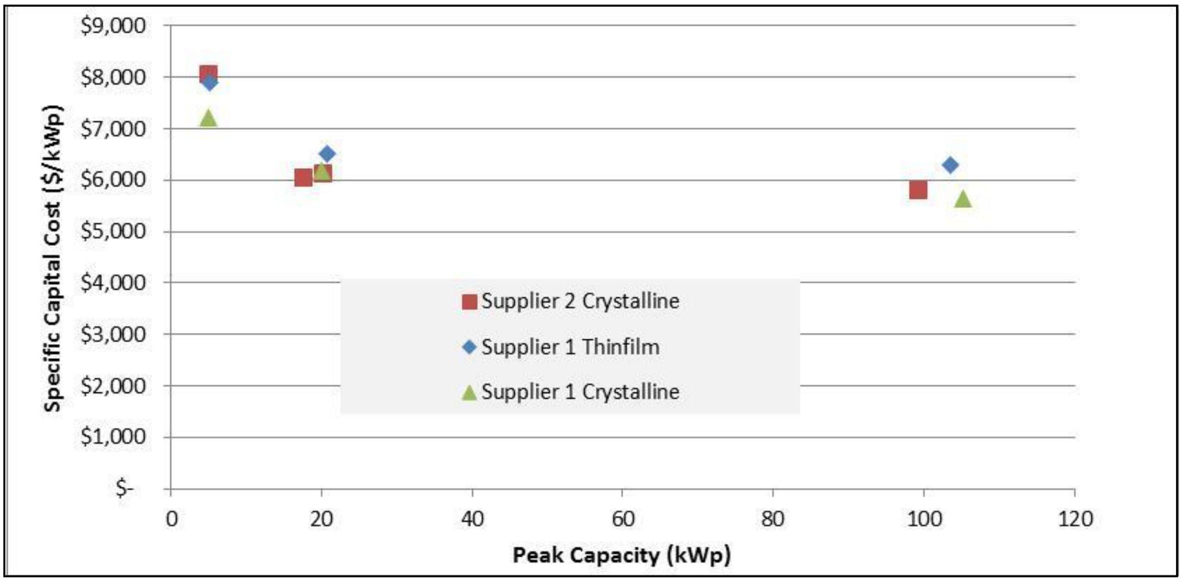


Figure 14: Quoted specific capital costs

Efficiencies of scale are clearly evident in Figure 14 for smaller systems (this is somewhat exaggerated by supplier 2 having specified an oversized inverter for the smallest system), but this effect levels off for larger systems (say above 20 kWp). The thin film systems quoted are slightly more expensive than the equivalent crystalline systems, which is somewhat but not fully compensated for by their higher predicted annual yields.

4.7 Cost/benefit analysis

For systems larger than 20 kWp a specific capital cost of $6,000/kWp for a crystalline system can now be considered a benchmark, providing 1,319 kWh annual yield per kWp. This system was analysed by Discounted Cashflow Analysis using the following assumptions:

- saved electricity costs: 14.01 c/kWh, plus 1.5 c/kWh of ETS charges still to flow through; increasing by 4% every year (being RDC's current cost and East Harbour's future electricity price trend)
- saved demand (lines) costs: 0.90 c/kWh, increasing by 2.5% every year
- degradation of annual yield from panels: 0.5% per year
- lifetime of system: 30 years
- all calculations before tax and depreciation

The assessment indicates a simple payback period for systems larger than 20 kWp of 19 years, with an Internal Rate of Return (IRR) of 4%. This is clearly not attractive on purely financial grounds, though the savings in greenhouse emissions and the other advantages discussed in the following chapter are additional benefits.

Economies of scale dictate that the largest system shows the best rate of return, but the size of the investment coupled with the low returns achieved makes implementation of the 100 kWp system unlikely. A 20 kWp system, which shows a 4% IRR would require a subsidy or cash contribution of around $28,000 (or 23% of the capital costs) to reach a return of 6% (this rate taken as the cost of borrowing for local authorities). In other words, the capital cost of PV systems this size would have to reduce still by 23% before returns around 6% could be achieved in this situation.

This means that the savings in greenhouse emissions and the other advantages discussed in the following chapter can be gained at moderate cost to the Council.

The economics of installing PV improve if avoided electricity costs are higher. For this 20 kWp example, avoided electricity costs would have to be around 19 c/kWh today before returns better than 6% are achieved. While commercial electricity prices in New Zealand currently are usually below this mark, domestic prices are above this mark today.

For commercial premises, system prices still would have to reduce by about 23% before interest rate like rates of return can be achieved. Provided past long term price decline trends are continuing, this situation is estimated to be only 4 to 5 years away.

Even at today's system prices and using energy cost escalation numbers as in the assumptions above, a 20 kWp system costing $120,000 would save electricity costs to a total of $231,000 over its 30 year lifetime, i.e. almost double the investment cost.

Once the investment for a PV system is made, the energy cost for the generated electricity is close to zero. The owner is insulated from future electricity price escalations, and investment into PV generation can be seen as a form of insurance against escalating prices in the future.

5. Why should local authorities be interested?

The 'Renewable Energy Policy Network for the 21st Century' in a recent draft report[15] had the following to say about the special role of local government in renewable policy setting:

> *"City and local governments can play a key role in encouraging renewable energy at the local level. The multiple roles of these local governments as decision-makers, planning authorities, managers of municipal infrastructure, and role models for citizens and*

[15] Global Status Report on Local Renewable Energy Policies
Working Draft, 12 June 2009, REN21 Renewable Energy Policy Network for the 21st Century
http://www.ren21.net/pdf/REN21_LRE2009_Jun12.pdf

businesses are crucial to the global transition to renewable energy now underway. It is their political mandate that makes local governments ideal drivers of change to govern and guide their communities, provide services, and manage municipal assets.

Most significantly, local governments have legislative and purchasing power that they can use to implement change in their own operations and in the wider community. With such capacity, local governments can become beacons for change in their region or country, demonstrating the effectiveness of policies and local action. And as early leaders among local governments take initiative, others can follow and improve upon the early efforts, replicating and scaling-up good practice and successful examples.

Local governments can also play a key role as facilitators of change, particularly in terms of raising awareness and facilitating community and business actions by a range of stakeholders. Often the participation of many different local, regional, and even national stakeholders is important to achieving planned outcomes. For example, 'model cities' in India and Brazil have been designed to involve local craftspeople, schools, scientists, and regional and national agencies. While cities are beginning to include renewable energy in urban planning, there are still relatively few explicit local renewable energy policies. Rather, renewable energy is often addressed indirectly, within other themes such as sustainability, climate change, clean transportation, and 'green' or 'eco' programs. Often, energy savings and energy efficiency are the main priorities, which makes sense due to the enormous opportunities for reducing demand. Reduced demand also enables renewables to meet a larger share of the remaining demand. However, it is also true that the potential for renewable energy is often overlooked, shortchanged, or needlessly postponed within these broader themes and programs.

The 'energy system of tomorrow', a system that could enable the realization of a 100% renewable future, will consist of a partially distributed, decentralized energy system with embedded energy storage, demand side management, and modern communications technologies. It also will likely include a large role for electric vehicles charged from local renewable energy sources. The role of local governments in shepherding and managing these transitions is highly significant. The future will likely reveal an interesting and multi-faceted interplay between local policies and these future energy transitions".

The same reference lists a wide range of policy measures adopted by city and local governments worldwide. The respective table for selected local renewable energy policies in Australia and New Zealand is repeated in Appendix 5. Notably Nelson is the only district in New Zealand which is listed for having a renewable energy policy.

Council buildings and other public buildings such as schools are particularly attractive as hosts for PV systems, since the ownership of the buildings and their use is usually more reliably assured long term. Councils are also owners of the infrastructure where overseas PV can be found in special applications, such as street lighting, park and reserve (security) lighting, bus shelters, noise barriers along motorways and carparks.

Figure 15: Special PV applications in municipal infrastructure

Building Permits

Many residential scale systems are currently installed without building permits, because the process is seen as too difficult and expensive. Few guidelines appear to exist covering how councils in New Zealand should handle building permits for PV systems. Small systems which are mounted flush to the roof surface have little impact on the building structure, outline or environs, and arguably should be included in the minor works schedules not requiring a permit. Larger systems, especially when mounted on elevated frames for optimum angle, can experience significant wind loadings and can have an impact on roof loadings. Framing systems and means of mounting need to be of a certified design or need to be assessed by a certified engineer.

The building consent process presents delays and increased cost for many installations. The main problems are[16]:

- a poor understanding within Councils about the technology (eg systems are often confused with solar hot water systems). This also leads to misconceptions about issues such as reflectivity.
- little understanding of how to assess compliance, which is not helped by the lack of standards.
- high and/or inconsistent fees
- within the PV industry, there is generally a poor understanding of the building consent process, resulting in incomplete applications or incorrect information supplied.

Possible solutions:

- development and promotion of relevant standards for products and installation
- standardization of approval processes agreed by all Councils (guidelines for Councils on handling micro-generation are currently being developed by SEANZ and EECA)
- solar access legislation
- PV information and education for Councils. CCP-NZ (Cities for Climate Protection program of ICLEI) could be used as a vehicle

6. Conclusion and next steps

The study shows that the roof space available on the Pacific building RDC head offices could support a PV system of up to 100 kWp capacity. Even at this size, the bulk of the electricity generated would be used 'in-house', with little power export. For the smaller systems considered (5 kWp and 20 kWp) no power export would be required, and the electrical interconnection would be straightforward; into a close-by distribution board.

When based solely on the avoided cost of electricity the financial payback on investment in PV is still longer than is usually considered commercially attractive, though costs are reducing and rates of return are now approaching bank finance rates. This means that while a system is hard to justify on purely financial grounds the savings in greenhouse emissions and the other advantages outlined below, and discussed more fully in the report, can be gained at low cost to the Council.

The multiple roles of local governments: as decision-makers, planning authorities, managers of municipal infrastructure, permitting authorities as well as educators and role models for citizens and businesses add special value to councils demonstrating renewable energy technology such as PV. By supporting PV demonstration facilities and projects local government can:

- show leadership in promoting renewable generation
- promote local growth and employment opportunities
- assist in growing economies of scale for the industry to reduce costs
- increase energy security and emergency power supply for their own premises
- assist resilience in the local electricity distribution grid
- promote a sustainable image for the region
- provide learning opportunities for council as permitting authority.

While a 100 kWp installation provides the best financial outcome, the installation of a 20 kWp PV system would realise most of the non-direct values listed above within a manageable budget and at a low cost over the lifetime of the project. Financial support may be obtainable from an energy industry partner such as Vector, who have supported similar systems, and who may contribute on the basis of the project's value to them.

[16] Assessment of the Future Costs and Performance of Solar Photovoltaic Technologies in New Zealand, New Zealand Ministry of Economic Development, April 2009

The installation of a PV system of around 20 kWp is seen as an appropriate sizing for the Rodney District Council to undertake, and it is recommended that the council moves towards implementation. Such a system would cost $120,000, but save a total of around $231,000 in electricity costs over its 30 year lifetime. Some support may be available for such a project.

The Orewa head office building is considered a very suitable location for a demonstration system. This can serve as a learning opportunity and an example to be followed for other council infrastructure in the wider Auckland area and around New Zealand.

Appendices

Appendix 1: Types of PV Technology

REVIEW OF CURRENT PV TECHNOLOGY STATUS AND DEVELOPMENTS

Source:
Chapter 2 in Assessment of the Future Costs and Performance of Solar Photovoltaic Technologies in New Zealand
by
IT Power Australia Pty Ltd and Southern Perspectives Ltd
April 2009

http://www.med.govt.nz/templates/MultipageDocumentPage____40706.aspx?&MSHiC=65001&L=0&W=photovoltaic+&Pre=&Post=

1 Crystalline or 1st Generation PV Cells

At present most solar cells use semiconductor silicon, which has a bandgap in the visible spectrum, i.e. can use photons with energy from sunlight to release electrons. Cells can be sliced from a single large crystal (c-Si), or from a cast of multi-crystalline silicon (mc-Si) material. Cells made from single crystal silicon have a higher efficiency then multi-crystalline cells, because there are no grain boundaries to block electron flows or to provide recombination sites. However, multi-crystalline silicon is cheaper and less energy intensive to produce and so has become increasingly popular.

The silicon purification and wafering processes are energy intensive and one of the main cost components of crystalline Silicon solar cells. In the past, wafers for solar cells were produced from semiconductor industry off-cuts. With the rapid increase in the solar market, dedicated solar silicon plants have been built which aim to reduce costs.

The cells are coated to minimise reflection of light or etched to increase reflection of scattered light back into the cell and to hence to maximise conversion of incoming light to electricity. Cells can be made 'bi-facial', allowing light to enter from both surfaces or they can have rear surface treatment to encourage internal reflection of light and hence enhance light capture. Metallic grids on the surface of the cells carry the current to the external circuit. The grids can be buried into a laser cut groove to minimise shading of the surface.

1.1 Ribbon and Dipped Silicon

To avoid the costly wafer process, thin sheets of crystalline silicon can be pulled from the silicon melt. Production costs are lower than for wafer based cells, while quality and hence efficiency can be as high as multi-crystalline product.

1.2 Crystalline Silicon Research Focus

Research on crystalline silicon cells focuses on improving efficiency, reducing wafer thickness, to reduce the use of high cost silicon, improving lifetimes and improving the manufacturing process.

2 Thin Film or 2nd Generation PV Cells

In order to reduce silicon usage further, and remove the expensive ingot and wafer processes, various methods are used to deposit semiconductor layers as 'thin films' directly onto useable substrates such as glass, metals, such as roofing sheets, and plastics of various types, including flexible sheets. Production costs are lower than for crystalline products, however, manufacturing scale-up has posed problems in the past. Nevertheless, from 2007, the production of thin films exceeded that of crystalline modules in the US (von Roedern, 2008), which may indicate that thin films will finally begin to capture significant market share. The IEA "Blue Map" Scenario for PV (IEA, 2008) expects thin films to comprise 40% of the PV market by 2030, up from 10% at present, and 35% by 2050, when 3rdGeneration products begin to take over.

2.1 Amorphous Silicon (a-Si:H)

To date the most successful of the thin film technologies is that of amorphous silicon, a disordered, non-crystalline allotrope of silicon, which can be deposited on a wide range of substrates in low temperature, continuous processes. Amorphous silicon cells are widely used in small consumer products, such as calculators and watches. In general, they have not yet achieved the efficiency and stability levels of crystalline silicon modules, but are finding a growing market in photovoltaic building products and other special purpose applications, as well as in large-scale solar power stations or ‘solar farms' where their lower cost is an advantage, as it is for other thin film products. The output from a-Si cells does not drop off as sharply as temperatures rise as occurs with crystalline silicon cells, which again is an advantage in building applications.

Multi-junction a-Si products, using layers of other materials, including Germanium, silicon carbide and nano crystalline silicon, are often used as means of increasing efficiency and stability.

2.2 Cadmium Telluride (CdTe)

CdTe has an ideal bandgap for capturing sunlight and a theoretical efficiency of 29.7%, making it ideal for single junction solar cells. It can also be produced using relatively inexpensive processes and therefore has been one of the main non-silicon thin film technologies so far pursued.

The technology has been the first to reach a production cost of 1 US$/W, a breakthrough which is allowing companies such as First Solar to offer large scale solar farm systems under power purchase agreements of US$0.12 – 0.15 per kWh (First Solar, 2008). The company aims to reduce module costs to US$0.65-0.70/Wp, system costs to US$2/Wp and efficiencies to 12% by 2012, which will result in an electricity cost of US$0.075/kWh in good sites (ibid).

There have been some concerns regarding the use of Cadmium, which is highly toxic. However, there is very little chance of Cd leaching into the environment from the double glass PV modules and companies such as First Solar have implemented a full recycling program for their modules. Life cycle studies have shown that cadmium emissions from CdTe PV modules are 90-300 times lower for the same kWh output than from coal fired power plants (Fthenakis, 2008). Of more concern in the longer term is availability of Tellurium (Watt, 1995).

2.3 Copper Indium (Gallium) Diselenide (CIS or CIGS)

Copper Indium Diselenide cells are the most efficient of the current commercially available thin films, at about 11%, with efficiencies as high as 19.9% achieved in the laboratory (http://www.nrel.gov/pv/thin_film/). The cells can be made with varying amounts of Indium and Gallium.

Only a few companies currently supply commercial modules. These include Wurth Solar, Global Solar Energy and Honda Soltec. Availability of Indium may be an issue for large scale production in the longer term (Watt, 1995).

2.4 Thin film Research and Development

The focus of thin film research is on improved efficiency, stability and lifetime, use of multiple layers of different materials, improved deposition and continuous processing techniques, as well as on scale manufacture to reduce costs.

3 Novel or 3rd Generation PV Cells

A range of novel concepts are under investigation and are expected to capture an increasing share of the PV market over time. Some of these, such as nano silicon cells, aim to combine the high efficiencies of crystalline products with the low manufacturing cost of thin films. Others, such as organic cells use entirely different processes and may form the basis of very low cost PV products, even if efficiencies remain relatively low. These technologies may compete with the 'power modules' of generation 1 and 2, or provide a new range of PV applications, built into consumer products, clothing or building materials and replacing batteries in a wide range of appliances. Hence, the emphasis may be on integration, aesthetics and low cost more than on efficiency and long life. The IEA (International Energy Agency, 2008) expects 3rd generation PV to account for half the market by 2050. Some of the many promising new technologies are described below. New Zealand research in this area is summarised in Table 5.6.

3.1 Dye sensitised solar cells (DSC)

DSC solar cells use photosynthetic principles to capture light and redox based cell structures to produce electricity. They are also referred to as Graetzel cells, after the original developer, Michael Graetzel. Small area modules are already being used for specific purpose applications, including mobile phone and other battery chargers, sometimes integrated into clothing, otherwise coated onto flexible and lightweight substrates for mobile use. The ability to operate in low light conditions, even indoors, and to be made in a range of colours, provides opportunities for new applications.

Laboratory efficiencies of 11 % have been achieved, and the potential for very low cost and low energy manufacture has seen a significant increase in R&D. Further development of this technology is focussing on different dyes, improved sealing or the use of solid electrolytes to overcome sealing issues, concentrating systems, improving stability and durability (Marsh, 2008).

3.2 Organic Cells

This new area of development aims to use organic, rather than inorganic materials to absorb sunlight and convert it to electricity. A range of conductive polymers, carbon fullerenes and other materials are being examined, which it is hoped will enable continuous, low cost production processes to be established. Hybrid organic and inorganic cells are also being investigated. Research programs aim to explore new materials, improve efficiency and stability, as well as developing processes that can be used for commercial production.

3.3 Nano-technology

Nano layers, between 0.1 and 100 nanometres, of semiconductor material can be structured so as to optimise light absorption over a range of different frequencies. These layers can be deposited onto a-Si, c-Si, conductive polymers or other substrates to increase the bandgap of light capture and hence the cell efficiency. Efficiencies as high as 60% are theoretically possible (Green, 2002). Nano structures made from silicon have the same stable properties as c-Si, but use far less material and can potentially be deposited more cheaply onto the substrate. Hence, in the short term, tandem or multi-layered structures built onto 1st or 2ndgeneration cells are likely to be used. A range of different structures, including carbon nanotubes and quantum dots are being investigated.

Appendix 2: Photographs of roof areas

Roofs A and B from Roof D

Roof C from Roof F

Roof D

Roof E (foreground) and Roof F (background)


Roof G from Roof F


Roof H


Roof I (in background)

Appendix 3: Quotes from supplier 1

Deleted in public report

Appendix 4: Quotes from supplier 2

Deleted in public report

Appendix 5: Australia and New Zealand – Selected Local Renewable Energy Policies

	Target setting	Regulation based on legal responsibility and jurisdiction				Operation of muni infrastructure			Voluntary actions and government as role model				Info/ promo
		Urban	Building	Taxes	Other	Purch	Invest	Utility	Demo	Grants	Land	Other	
Adelaide	X	X				X	X		X	X			X
Alice Springs		X						X	X	X		X	
Ballarat	X		X			X							
Blacktown									X			X	X
Brisbane	X		X										X
Clarence Vly.	X		X										
Hepburn Sh.	X					X	X						X
Melbourne	X	X				X			X			X	
Moreland	X											X	X
Nelson (NZ)	X	X					X					X	X
New Castle	X					X						X	X
Perth	X				X						X		X
Sydney	X					X	X					X	X
Townsville		X							X			X	X

From: Global Status Report on Local Renewable Energy Policies
Working Draft, 12 June 2009, REN21 Renewable Energy Policy Network for the 21st Century
http://www.ren21.net/pdf/REN21_LRE2009_Jun12.pdf

Appendix 6: Links to further information

www.energywise.govt.nz/how-to-be-energy-efficient/generating-renewable-energy-at-home/solar-electricity-generation

www.energywise.govt.nz/node/3400

www.pvresources.com

http://www.epia.org/publications/epia-publications.html

www.ren21.net

www.med.govt.nz

www.solarbuzz.com

http://www.niwa.co.nz/our-services/online-services/solarview/solarviewexplanation

http://www.iea-pvps.org/