SOLAR PHOTOVOLTAIC GENERATION (PV)

Overview

Australians are installing rooftop solar photovoltaic (PV) systems on a large scale, with households leading the way. In the two years from the end of 2010 to the end of 2012, the proportion of private dwellings with a solar PV system rose from 3% to 10%, or one million households. Solar PV systems make an effective long-term investment, as cuts in component prices have offset recent reductions in government incentives. As the cost trend continues, solar PV systems will become even more affordable.

The ZCA Buildings Plan calls for an accelerated uptake of solar PV, reaching a full uptake on suitable buildings by 2023. In practice some suitable buildings will remain bare due to owners' preferences; the size of this group is difficult to predict. This plan assumes that any shortfall in uptake will be compensated for in other areas, such shading car parks, facades, roads or irrigation channels.

The Proposed Solution: Technologies or Strategies Employed – Solar PV

The Australian solar PV industry has grown rapidly since 2008 and has proved the techniques to install rooftop solar PV systems in large numbers. For example during calendar year 2012, Australians installed 336,000 sytems, totalling 974 MW of new on-site generation capacity. In 2012 the industry employed more than 15,000 people.

Solar panels are made up of semiconductor solar cells which convert light-energy (photons) from the sun directly into electricity using the photovoltaic effect.

The Buildings Plan proposes the use of grid-connected systems, generating electricity on-site to offset consumption within the building. Solar panels mounted on the roof generate direct current (DC) electricity, and an inverter converts this to alternating current (AC) at 240 volts. If the solar system is not producing enough electricity to run the whole building, the balance is purchased from the grid, as usual. If on-site generation exceeds consumption, the inverter feeds it into the electrical grid via the building's meter. The electricity distributor then transports this excess energy to supply electricity consumers nearby. The electricity grid sees solar PV as reduced demand. The Buildings Plan requires little more technical innovation in the solar PV field, as it requires no new technology.

Benefits

Solar PV systems:

- Allow Australians to achieve net energy independence by generating their own electricity.
- Enhance behaviour change, through incentives to cut electricity consumption.

- Provide attractive long-term investment returns that are low-risk and probably not treated as taxable income[160].
- Are safe, long-lasting and almost maintenance-free[161].
- Reduce wholesale electricity prices, by cutting daytime demand[162].
- Avoid electricity network capacity upgrades by reducing maximum demand[163].

Financial benefits are not restricted to building owners. Solar financing schemes already common in the USA allow investors to receive dividends from capital invested over many roofs.

Energy Demand-Reduction Potential

Over the last few years, the uptake of Solar PV has consistently out-paced published forecasts. Solar PV's potential is huge, being able to supply all of the annual energy required by homes and some of that required by non-residential buildings, after the retrofits detailed elsewhere in this plan.

Current Picture

The average size of currently installed solar PV systems is 2.5 kW, which equates to around 13 190 W solar panels (typical in 2013). A system of this size generates approximately 3,500 kWh of energy per year, offsetting about half of a typical households electrical energy consumption. Installations are increasing in size; the average in January 2011 and April 2013 were 2.28 kW and 3.8 kW respectively.As of May 2013, the total installed capacity of solar PV systems was over 2.5 GW [157].

In the financial year 2011-2012, solar PV systems generated 1,702 GWh [165], offsetting approximately 0.9% of total electrical energy consumption. ([166], Ch 3, p 1) This equates to approximately 1.3% of 2020 household energy consumption pre-retrofit.

Future Picture

The ZCA Buildings Plan includes an accelerated uptake of solar PV, resulting in 100% of suitable buildings hosting a system by 2023. The total roof area covered by solar panels will be 204 square kilometres. For comparison, this is approximately 15% of the footprint of all buildings or ten times the total area covered by private swimming pools.

At full solar PV uptake, a typical houses solar PV system will be rated at 4.5 kW [167],which equates to around 18 solar panels. With this level of solar PV uptake, residences will host systems rated in total at 31 GW and will generate on-site energy approximating 46,000 GWh annually, or 102% of post-retrofit residential building energy consumption. This varies by state – in less sunny states annual energy is not completely offset. Of course residences are not independent from the grid, as solar generation varies by month and time of day.

Solar PV systems on non-residential buildings will be rated in total at 2 GW and will generate approximately 4 GWh annually, or 13% of post-retrofit non-residential building energy consumption.

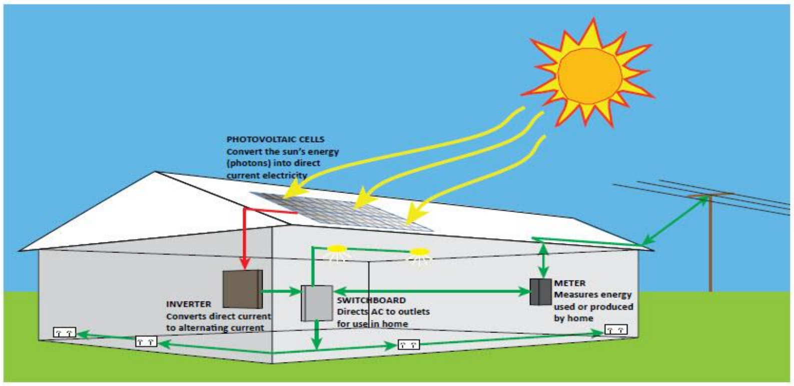

FIGURE 3.44
How grid-connected solar works. [Sunwave Solar]

The combined total of 33 GW is nominally equivalent to 22 coal-fired power plants. For details of the analysis and modelling behind the estimates of on-site generation, please see Part 5.

Specific Implementation Recommendations

As noted above, this plan proposes that grid-connected solar PV systems be installed on all suitable buildings.

For maximum generation throughout the year, panels should be oriented between north-east and north-west. Shading even a part of the system cuts output dramatically. Building owners should check the path of shadows cast by nearby trees and buildings for summer/winter and morning/ evening. It is also important to consider future tree growth and likely building activity.

Patterns of building electricity consumption should also be considered. If occupants rely on late afternoon air-conditioning, a west-facing system may be effective to offset this consumption.

Deployed on a larger scale, this technique trims afternoon and evening peak demand on the grid, postponing costs from additional network and generation capacity.

The optimum tilt angle for solar panels increases with distance from the equator. Grid-connect systems should ideally be tilted slightly less than the angle of latitude for the installation site, to maximise generation during summer. On the other hand, off-grid systems should be tilted at an angle greater than latitude to maximise generation during winter when sunlight is scarce [5].

Where the roof 's tilt is within about 20° of the ideal angle, the expense of a tilt frame may not be justified – a better return on this money may be obtained from additional panels instead. Even a near-flat installation may be best suited in the case of large flat roofs, to avoid adjacent rows of panels being shaded.

One example of current best-available technology (BAT) solar panel is SunPower's E20 Series 250 W module. Its high conversion efficiency of 20% allows more generation from the same roof space. However where roof space is not at a constraint, lower-efficiency panels are currently more cost-effective.

Current inverters reach operating efficiencies of 95-98%. Inverters above 3 kW typically contain more than one Maximum Power Point Tracker, allowing solar panels to be mounted in different orientations on the roof.

Since the quality of components varies widely, building owners should check the reputation of installers and component brands, to avoid potential future performance issues.

It is recommended that billing be conducted on a net basis. Within each half-hour billing interval, solar PV generation should be netted off consumption, effectively credited at the consumption tariff rate. This contrasts with gross billing, in which such generation receives the feed-in tariff (currently lower than the consumption tariff, typically). Bills should clearly itemise the solar PV system's generation.

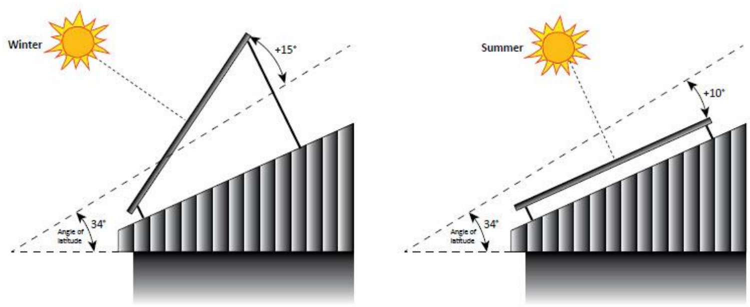

FIGURE 3.45
Tilt angles to maximise summer and winter generation, Sydney example.

Costs

Electricity generated by solar PV is now cheaper than the typical Australian residential retail electricity tariff ("socket parity"), and is drawing closer to the average wholesale electricity price ("grid parity"). The Levelised Cost of Electricity (LCOE) generated by solar PV in 2012 was approximately 15 c/kWh, while residential retail tariffs are typically above 20 c/kWh [168].

The cost of electricity from solar PV will continue to decrease. The Australian Bureau of Resources and Energy Economics (BREE) expects the solar PV LCOE will drop by 41% between 2012 and 2020, which equates to an average annual decline of 6.3%. ([169] pp71)

For 5kW solar PV systems, the 2013 actual installed cost per watt is $1.98 post-rebate, which equates to $2.13 pre-rebate [170]. Allowing for price drops, the average installed cost per watt excluding rebates will decline to $1.11 over the 10-year period, with a mid-point of $1.54. Technology advances over the implementation period are captured by specifying best currently available technology, the 20% efficient Sunpower E20 series module.

The cost of installing a typical home's 4.5 kW system is $6,930 excluding rebates. At an average installation rate of 2.8 GW per year, the average annual investment required during the ten-year plan is $4.3 billion (excluding rebates). This is similar to the $3.8 billion invested in 2011 [171]. For comparison, Australians spend approximately $1.5 billion each year on private swimming pools (including maintenance and building new pools).

Product Development

The following developments hold the promise to increase the utility and cost-effectiveness of solar PV systems. They are not included in modelling, which makes the Buildings Plan conservative in this respect.

Time-Shifting On-Site Generation with Battery Storage

As noted below on smart grids, batteries can be used to smooth peak demands within a building or across the grid. When used as part of a solar PV installation, electricity in excess of consumption can be stored for use later, or to be fed into the grid at times of higher price. For example, Germany introduced subsidies in May 2013 to encourage the uptake of grid-connected battery storage [172]. Large-scale uptake is dependent on further battery cost reductions.

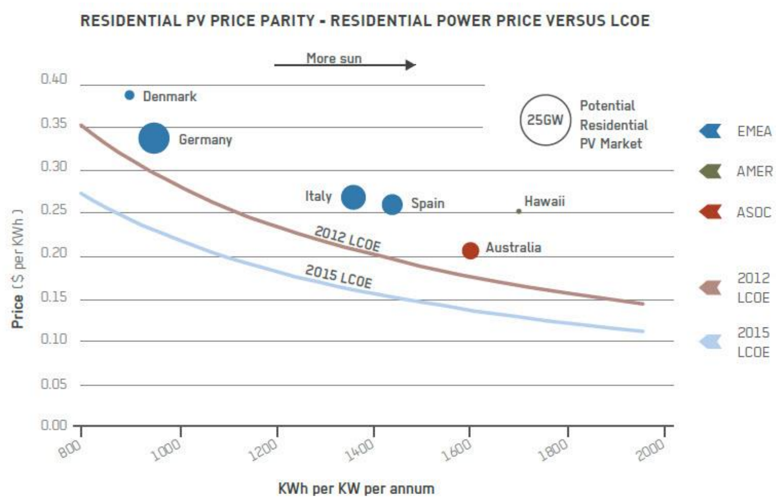

FIGURE 3.46

Levelised Cost Of Electricity, Australia vs selected countries. [Source: Bloomberg New Energy Finance.]

Note: LCOE based on 6% weighted average cost of capital, 0.7%/year module degradation, 1% capex as Q&M annually. $3.01/W capex assumed for 2012, $2/W for 2015.

BIPV

Building Integrated Photovoltaic (BIPV) refers to photovoltaic or solar cells that are integrated into the building envelope, for example, roof, walls and windows. In addition to generating electricity, BIPV can also provide structural stability, thermal insulation, shading, natural lighting, and protection from water and other elements. BIPV product development has been ongoing for the past 30 years, but uptake has been slow in comparison to conventional rackmounted PV due to its higher installation cost per-kW. BIPV has the potential to increase Australia's total solar PV generation, but has not been specified in this plan.

Barriers to Implementation

When installing a solar PV system, building owners face barriers and risks outside their control. To sustain an accelerated uptake of solar PV, Australia must mitigate these barriers.

Connection approval. The local electricity distributor may reject the application to install solar PV because it is unable to manage additional electricity fed into its network.

Distribution network constraints. Generation may be restricted by over-voltage in the street's power lines.

Council restrictions. Planning rules such as heritage overlays preclude visible installations on many buildings.

Building ownership. In multi-occupancy buildings such as apartment blocks, it is difficult to fairly apportion installation investment and returns.

Tenancy arrangements. Landlords may expect little return from installing a system, since their tenant is the direct beneficiary.

Electricity tariffs. The electricity distributor might reduce the value of energy offset by the solar PV system, by shifting charges from energy into the fixed daily charge.

Relocation. Building owners may not recoup the value of the solar PV system upon selling the property.

Feed-In Tariff uncertainty. Some feed-in tariffs are subject to revision with little notice.

For further information on network constraints, please see below on smart grids.

Other Implementation Options

Off-grid installations. In locations served by a connection to the grid, it is possible to disconnect and install an off-grid solar PV system with battery storage. However, the cost of such a system is many times more than a grid-connected system without battery storage and is currently uneconomical. Also any production exceeding battery capacity is wasted as it cannot be fed into the grid. Hence, grid-connected systems are specified in this plan.

Adjustable frames. Adjustable frames allow solar panels to be dynamically oriented to face the sun, on either one or two axes, increasing electricity production. Tracking mechanisms are available for automation. However, adjustable frames add complexity and must be strong enough to withstand high winds. Since it is generally more advantageous to use simple fixed frames and increase the number of solar panels, adjustable frames are not specified in this plan.

Micro-inverters. Solar PV installations typically include one or more central string inverters, which convert the direct (DC) current created by solar panels into 240 volt alternating current (AC) suitable for powering appliances and feeding back into the grid. A recent innovation in inverter technology is the introduction of micro-inverters. Micro-inverters are built into each solar panel and convert the output of each panel into 240 volt AC in-situ, eliminating the need for a string inverter. Micro-inverters have the potential to increase yield by reducing the impact of shading, and facilitate installation on small roof surfaces, but are currently more expensive than string inverters. This is likely to change in future if micro-inverters are deployed in volume. For these reasons, micro-inverters are not specified in this plan.

Source: http://decarboni.se/publications/zero-carbon-australia-buildings-plan/8-onsite-electricity-generation