Six years experience with an urban photovoltaic system

Jonathon Thwaites, Physicist, University of Western Australia
jthwaites@admin.uwa.edu.au

Introduction

Six years experience relating to the use of a grid connected Photovoltaic (PV) system installed on a urban dwelling is presented. Energy production and electricity usage data is reviewed for a typical family home in Perth. The system has been data logged and energy bill information has been combined with PV system data to give a comprehensive picture of electrical energy use, production, purchase and sale. The payback period, between 38 and 78 years, is reviewed. The affect of the Australian Greenhouse Office (AGO) rebate, introduced in Jan 2000, is reviewed in relation to its ability to act as an incentive to install solar power on urban homes in Perth and found to be severely wanting. For more information, see http://www.sustainability.ofm.uwa.edu.au/welcome/solar_power_urban2

Experience with the Office of the Renewable Energy Regulator (ORER) and production of Renewable Energy Certificates (RECS) is presented.

AGO incentive rebates

On 1st January 2000 the AGO introduced a rebate scheme in order to encourage individuals to install PV systems on their residential dwellings. The rebate was applied as at the rate of $AUD5.50 per Watt of installed new PV panels and capped at 1.5 kW (1,500 Watts), or a total of $8,250. A typical installed and operational 1.5 kW PV system in early 2000 required a capital outlay of approximately $16,500. The Howard Government introduced a Goods and Services Tax (GST) on renewable energy equipment in July 2006 and immediately added 10% to the price of the system. Six months after the introduction of the rebate the system price had risen by $8,000 to $24,000 totally absorbing the rebate, neutralizing its incentive to system purchasers in Western Australia.

Due to the high demand on funds, and to extend the rebate to a larger number of systems, the rebate was reduced to $5.00 per Watt of PV or a total of $7,500 for residential dwellings, on 1st October 2000. The rebate was again changed in 2005 so that a maximum of $4,000 was available for a 1 kW system.

Grid connected and stand alone systems

Installations may be grid connected or stand alone. Most urban systems, or where the grid is available, will generally be grid connected thus avoiding the need to have a battery bank. With grid connected systems the PV panels are connected to the grid through an inverter and the grid replaces the function of the battery bank. In order to supply power into the grid, the energy producer must come to an agreement with the grid owner or operator. In Western Australia the user must sign a power purchase agreement with the electricity utility.

Tariffs, Net metering, Greenpower, Smartpower

With grid connected systems energy is sold onto the grid when production exceeds use, and purchased from the grid at other times – this is called Net metering. A GST of 10% is charged for energy sold into the grid and represents a differential of 10% between purchase and sale of electricity, detrimental to the small producer.

Most utilities have tariff rates that vary over the day and for different times of the year and reflect the need for the energy supplier to meet the varying demand for energy use over the day. Electricity production systems generally have a large inertial characteristic and are therefore unable to change production output quickly. The variable tariff system in Western

Australia is called Smartpower and the tariff varies between approximately 8 c and 19 c per kW.h.

Under the Greenpower scheme introduced in Western Australia individuals may nominate to purchase energy from renewable sources over the grid by paying a premium of aproximately 3 cent per unit kWh above the normal retail price. The added value of domestically produced renewable energy is not passed on the domestic producer.

Design and installation

The major components, inverter and PV panels, of the PV system were manufactured in Europe and have shown good reliability and efficiency in Europe. Figure 1 shows the main components of the PV system. The major components of the system are

- PV panels
- Grid interactive inverter
- Metering
- Switchgear and wiring
- Mounting system for panels

PV Panels

In the system there are 16 x 90 Watt Photowatt PW 90 polycrystaline panels in one string (that is in series). At full power the system operates at approximately 255 V DC and 6.5 Amps.

Grid interactive inverter

The inverter on the system is a Fronius Midi and is rated at 1500 Watts. The working range is from 1200 to 2000 Watts. The maximum inverter efficiency is given as 93% at 1500 Watts and varies with input power, Figure 1. The average power into the inverter is approximately 700 Watts and at this power the inverter is approximately 83% efficient.

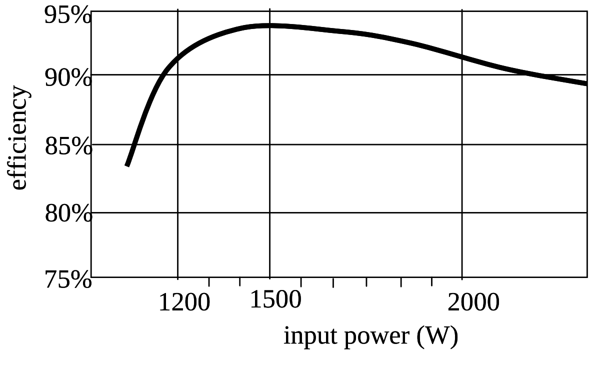


Figure 1. Inverter efficiency as a function input power

Datalogger

The inverter came supplied with a data logging facility. This device monitors various parameters of the system and records them for display or manipulation on a computer. It also gives an instantaneous display of energy production during the day as shown in Figure 2 a, b. Data logging is essential if the system is to be properly managed and to encourage an interest in the system.

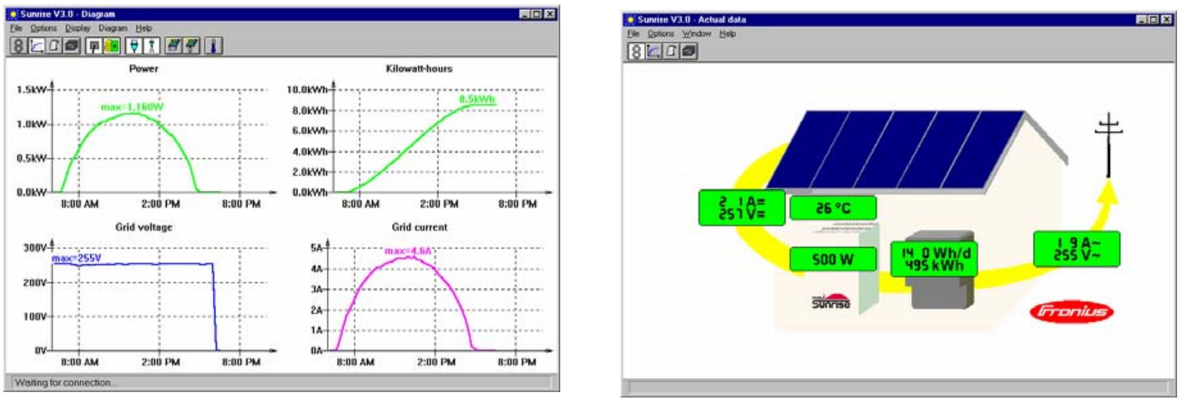


Figure 2 a, b   Typical inverter datalogger output screens

Wiring and switch gear
Wiring and mounting of the inverter and panels needs to carried out carefully and neatly and take into account the high currents in the system.

Switchgear needs to be rated for DC switching. Over rated AC switches will generally not be sufficient for higher voltage DC circuits. AC switch gear was installed by the supplier and had to subsequently be upgraded to DC switch gear.

Mounting of Panels
Mounting of the panels involves a number of important issues, these are:

- direction
- angle of mounting
- shadowing effects of nearby buildings and trees
- mechanical integrity
- natural connective cooling
- collection of dirt on the panel surface and frames and mounting brackets
- compatibility of roofing, panel, fixing screws and framing materials

The system is mounted on a dwelling with a corrugated iron roof. Two large areas of suitable roof space at different angles, approximately 35° and 25° from the horizontal are available. The panels were incorrectly mounted on that part of the roof with the shallower pitch.

The panels need to mounted in such a way that they will not lift or blow away in the strongest winds reasonably expected in the area. The components of the mounting system should be corrosion resistant and compatible with the roofing materials. Location of roofing purlins and rafters may determine the fixing system used. A well design mounting system should be flexible enough to accommodate any sort of roofing structure.

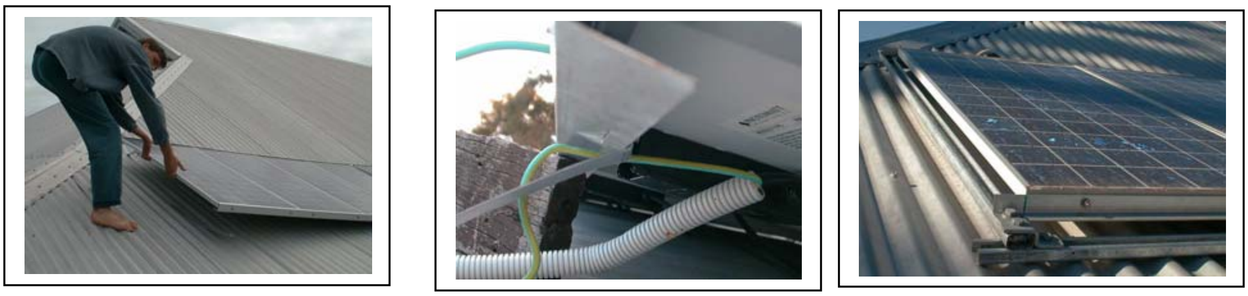


Figure 3a Mounting straps   3b Folded strap into channel   3c New mounting system

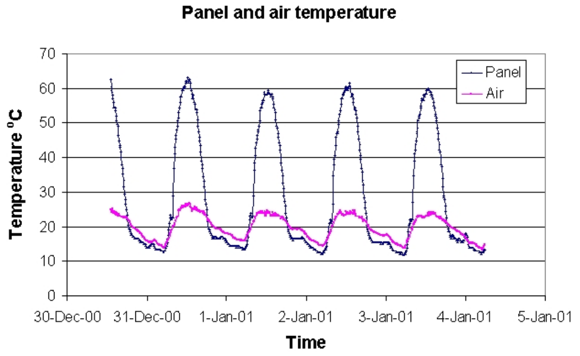
The mounting system used for the panels in this system were totally inadequate. Galcvanised strapping, 25 mm wide 1 mm thick and 300 mm long, was used to attach the panels to the roof. This fixing system allowed the panels to be lifted and rotated on the 300 mm strap radius off the roof with only the weight of the panels providing any resistance, Figures 3 a, b. The panels were remounted by the owner using a robust framing system, Figure 3c. Galvanized metal is incompatible with zinc alum metal sheeting.

Convective cooling

PV panel efficiency varies with the temperature of the panels and it is important that air can flow naturally behind the panels to help keep them cool. Natural convective cooling, with cool air rising behind the panels as it is heated, is required. An unobstructed path for air for flow behind the panels up the slop of the roof is preferred. The panels as mounted by the installer provided very little room for natural convective cooling and severely impacted on efficiency of the panels, Figure 5. Generally the efficiency of the panels is reduced by approximately 2.5% per ^{o}C above an ambient temperature of 25 ^{o}C. Panels could be expected to reach over 60 ^{o}C on a still summer day with air temperature of 30 ^{o}C as is indicated in Figure 4 a, b and would correspond to a 30% loss in efficiency. Figure 4b shows a fitted line to the data for panel temperature as it depends on air temperature.

Figure 4a Panel and air temperature

Figure 4b Linear regression - panel temperature as a function of air temperature



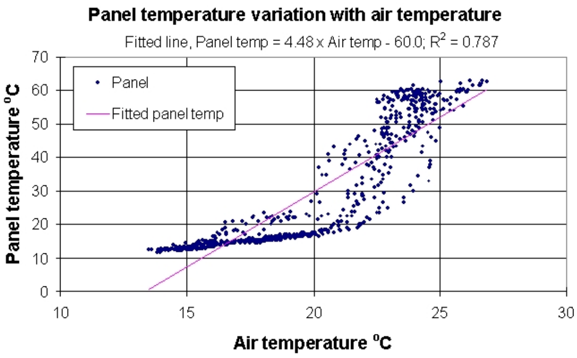


Figure 5 Air gap below panels on my system

Energy production

The system produces approximately 30% of the electricity needs of the household and the household is a relatively low user of electricity in its area. Average electricity usage over the year in the dwelling is approximately 15 kW.h per day and the system should produce approximately 5 kW.h of this. This amounts, at the current tariff, to about $222 of electricity per year. Figure 6 shows the overall electrical energy data for the dwelling for a six year period. The points are based on the 60 day billing period of the electricity utility.

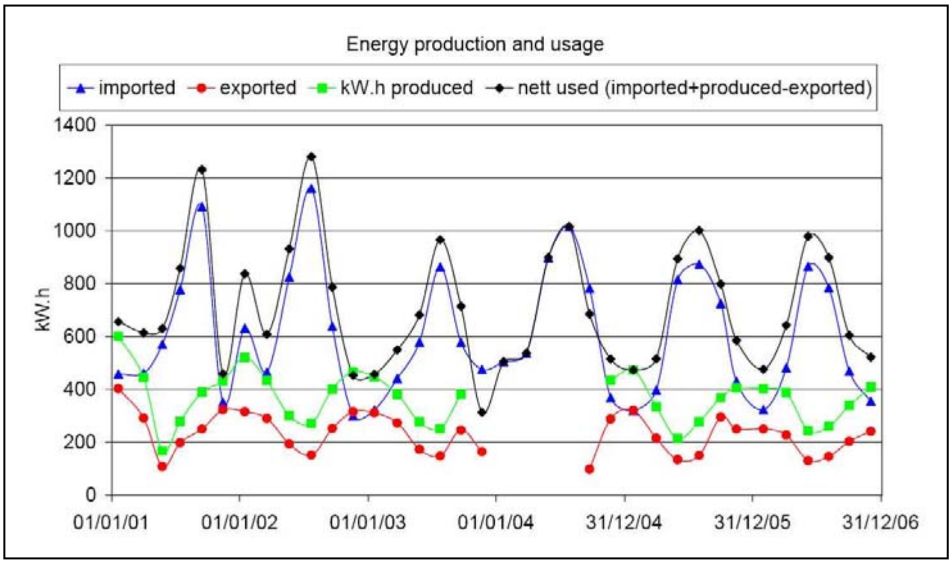


Figure 6. Overall electrical energy data for the dwelling for a six year period.

The system will pay for itself in saved electricity in about 38 years. If the system was bought 12 months later it would have cost the owner AUD$16,000 instead of AUD$8,500 and would have taken approximately 78 years to pay for itself. Note the system is likely to have life of 20 years only and the owner can expect to make a net financial loss of approximately AUD$18,000 over the life of the system.

Renewable Energy Certificates (RECS)

The ORER oversees a system for creating RECS. They are only creatable for complete MW.h in a year. Every year approx. 0.99 MW.h of 1.99 MW.h of energy produced by the system cannot be translated into RECS (ie ~48%). This is a serious disadvantage in this system for small producers. RECS add little value to the overall system (approximately 13 %) over its lifetime and are not tradable internationally as Australia has not signed the Kyoto accord.

Main technical failures

Panels mounted with no air gap – natural convective cooling inadequate
Panels mounting system mechanically inadequate to secure them
Panels mounted on wrong part of roof – angle not optimal for latitude
Inverter/panels DC isolation switch inadequate – underrated switches used 450 Volt AC, 10 A to switch 255 Volt DC, 6.5 A
Inverter failure - inverter rated for indoor installation not semi outdoor - eventually dust and damp sea air caused the main IC to short on its pins
Inverter not conforming to Australian Standard – on repair could not be sold but can be used on original site only
Inverter not optimised for input power level

Incentive failure

Green power premium not passed on to producer
10% GST on energy production – GST on renewables in June 2000
10% GST on solar equipment – no tax prior to GST in June2006
Rebate on equipment was clearly shown to be sub optimal to encourage uptake in Germany prior to the AGO rebate introduction. Germany changed to an incentive based on premium on energy produced – the final output was encouraged not something halfway.
Rebates totally taken up by GST and supplier/installers within 6 months – AGO incentive for purchasers of systems defeated.
ORER - RECs only creatable for complete MW.h in a year. Every year approx. 0.99 MW.h of 1.99 MW.h of energy I produced cannot be translated into RECS (~48%) – a disadvantage for small producers.
RECs not tradable internationally – not signed up to Kyoto.
AGO rebate not available for extending system – why not?

Metering failure

Electricity utility wont provide detailed data from meters – should allow access to logged data on meter (read only).
Meter and bill data is set up in a way that makes assessment of the overall energy picture for the dwelling near on impossible without significant computing skills and detailed inverter data logging on a short time interval (~5 min). Data points can only be determined for billing period intervals (~60 days).
Electricity meter is hard (near on impossible to make sense of) or read at any time.
Is not really net metering as it does not allow production to be assessed.

Conclusion

A PV system installed on a dwelling will pay for itself in approximately 78 years, but will have a significantly shorter working life. The net outcome is that a person installing a 1.5 kW system can expect to loose AUD$18,000 over the life time of the system. Incentive schemes are hopelessly inadequate and regulators and electricity utilities have given little practical support to encourage the uptake of urban PV.

- Overall comment - no thought has been given to customer convenience in trying to assess the value of their renewable energy system – creates disinterest.
- Outcome - confusion, misleading information, disappointment, reduced uptake.
- Reality - don't install urban PV unless mislead, a technophile or want to lose money.
- What to do - review incentive and make some useful changes - stop defending a failure as if it isn't one.
- Supplier refused to replace inverter or correct panel mounting system.
- System was approved despite faults with switchgear, mounting and inverter placement.