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Original article

Solar panels: Real efficiencies, potential productions and payback periods for major Australian cities

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ABSTRACT

In spite of continuous campaign and efforts large scale adoptions of solar panels are yet to be materialised, mainly due to lack of confidence on potential energy savings. This paper presents real efficiencies achieved from four houses in two Australian cities; Melbourne and Adelaide. Based on actual solar energy productions and actual incoming solar radiations during a monitoring period, efficiencies of solar panels installed in the selected houses were calculated. It was found that among the four monitored houses, a maximum efficiency of 7% was achieved. Considering this maximum achievable efficiency and annual average incoming solar radiations, potentials of energy savings for eight major cities of Australia are presented considering two different solar panel systems; 2 kW and 5 kW. It was found that for a typical 4-members household winter-demand, a 2 kW system and 5 kW system is expected to generate 19–29% and 49–73% of total energy. In addition, considering the current costs and expected savings, payback periods of different sized solar systems are presented for the eight cities.

Introduction

To achieve global sustainability, several government and private authorities have been promoting different sustainable energy options, among which solar panels are most widely used. In Australia, the government has been offering incentives/subsidies to the residents installing solar panels to augment their energy demands. However, large scale adoption is still not happening. One of the main reasons for this is uncertainty on claimed efficiencies and lack of confidence on payback period. According to Bamberg and Schmidt [2], social norms emerge as having a strong effect on one's intention to invest. What seems to matter to consumers is the belief that global warming is a global problem that everybody must deal with and take action. Social influences can be very significant in this regard depending on one's environment [17]. In a study conducted by Ozaki [11] the decision-making process consumers adopt when deciding to invest in renewable energy was analysed in-depth. The results of this study showed that possessing "pro-green" attitudes towards pro-environmental behaviours was not enough reason for adoption of a solar energy system. Ozaki [11] further demonstrated a sense of uncertainty about the relatively new energy source emerged as being the primary deterrent for people adopting renewable energy sources. There is a consensus of uncertainty about the quality, efficiency and reliability of alternate energy sources. Switching to a renewable energy source was also considered a hassle, which further affected the adoption of renewable energy.

As Australia receives the highest amount of solar radiation of any continent in the world, it has become a focal point of research for the solar panel industry [3]. The solar radiation that Australia absorbs each year is over ten thousand times the amount it uses each year. As such there is much potential for more advanced solar energy developments. In Australia, solar photovoltaic cell is the fastest growing of all related solar panel technologies [7]. However, in general real efficiencies of installed solar panels are lower than expected/claimed. As the panels get heated during operation/sunlight, its energy producing efficiency goes down. Different studies were done to overcome this issue of heated solar panel. Thakur et al. [16] investigated the improvements of efficiency using solar panels immersed in a liquid to keep those cool. Parmar et al. [12] investigated effectiveness of using roller-style dust remover to keep the panels clean from dust, which obstruct absorption of sunlight on the panel surface. Balamuralikrishnan et al. [1] investigated using optical filters on solar panel surface to reduce reflections of sunlight from solar panel surface, due to which some portion of sunlight is reflected back (i.e. lost). However, all these additional features attract additional costs to the solar panel, which are quite expensive in some countries.

Although, solar energy is emerging as one of the most cost-effective and affordable sources of electricity in Australia, a majority of the people still do not have a positive perception on expected payback

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Table 1
Details of solar measurement stations selected for spatial variation study.

City	Station location	Station number	Latitude	Longitude
Melbourne	Laverton	87031	37.86S	144.76E
	Ringwood	86379	37.79S	145.24E
	Dandenong	86224	37.98S	145.22E
	Olympic Park	86338	37.83S	144.98E
Adelaide	Gawler	23107	34.60S	138.74E
	Unley	23119	34.94S	138.60E
	McLaren Vale	23876	35.23S	138.54E
	Lobethal	23726	34.90S	138.87E
Brisbane	Caboolture	40975	27.08S	152.95E
	Ipswich	40101	27.61S	152.76E
	Brisbane City	40690	27.47S	153.03E
	Romani	40894	27.85S	152.91E
Sydney	Observatory Hill	066062	33.86S	151.21E
	Airport	066037	33.95S	151.17E
	Parramatta	067041	33.82S	151.01E
	Terrey Hills	066059	33.69S	151.22E

period. According to Flannery and Sahajwalla [7] in Australia, on average a solar panel system with a minimum life expectancy of 20 years has the total cost of setting it up can be reimbursed through savings within seven years. However, this payback period can differ based on numerous factors such as; the actual type of solar panel system, the cost of installation, how the panels are arranged, the amount of unobstructed sunlight hitting the panels, the amount of energy used compared to the amount generated and the actual physical location [7].

In Australia, when solar panel owners generate more electricity than what they actually use, the excess energy is rerouted back into the electrical grid allowing the owners to be paid for the total amount they produce. These payments occur in one of two ways; gross feed-in tariff schemes or net feed-in tariff schemes. Net feed-in tariff scheme offer payments for the excess amount of energy returned to the electricity grid, while gross feed-in tariff scheme offer payments for the total amount of energy generated regardless of whether it is returned to the grid or not [7]. Due to these tariff schemes, in some areas electricity generated by solar panels has reached cost competitiveness with other traditional and popular methods [5]. With all these positive features and government incentives, adoptions of solar panels in Australia is not occurring at expected rate as most of the end-users are not convinced with the claimed expected savings and payback periods. In general, solar panel producers/sellers tend to claim a high level of savings and shorter payback periods. Anecdotal evidence in support of their claims are often missing. To overcome this issue, this study independently investigated real efficiencies of solar panels achieved from four individual houses (in two different cities) in Australia. Based on maximum achievable efficiency and total annual incoming solar radiations, potentials of energy savings through household solar panels for eight major cities of Australia are presented in this study. Also, based on all the associated costs of solar panel installation, government incentive and expected energy savings, payback periods of different sized solar panel systems (1 kW–5 kW) for the eight major cities are presented.

Table 3
Incoming solar radiations and climatic conditions of the selected cities.

City	Mean Annual Solar Radiation (MJ/m^2)	Mean Maximum Temperature (°C)	Mean Minimum Temperature (°C)	Mean Annual Rainfall (mm)
Melbourne	5511	19.7	9.3	686.5
Adelaide	6387	21.6	11.5	442.7
Sydney	5986	21.7	13.8	1215.7
Brisbane	6789	26.5	16.3	1021.6
Cairns	7190	29.0	20.8	2271.5
Perth	7044	24.7	12.8	727.5
Canberra	6278	21.0	6.7	643.1
Darwin	7738	32.1	23.2	1733

Methodology and data

First of all, to test the representativeness of solar radiation data from a particular station for the whole city (especially for a large city), measured solar radiation data was collected from four remote parts of four largest cities in Australia; Sydney, Melbourne, Brisbane and Adelaide. Earlier, Imteaz et al. [10,9,8] presented significant spatial variations of one of the climatic variables, rainfall for some of these cities. Spatial variations of annual average incoming solar radiations of the selected stations in each city were compared. Details of the locations of each selected station in all the selected cities are presented in Table 1.

For the evaluations of existing solar panels' efficiencies, four houses (two from each city of Melbourne and Adelaide) were selected where solar panels were installed and have been in operation for several years. Houses were selected based on accessibility of data on household electricity uses/bill and solar panels' properties. In Australia, houses having solar panels receive electricity bills having information on solar energy produced, used and/or supplied to the main grid. For the selected houses for particular monitoring periods (depending on the data availability), the above information was collected from the individual households' electricity bills. Incoming solar radiation data from the nearby station of each selected house was collected from the Bureau of Meteorology website [4]. Details of the locations of the selected houses, solar panels' properties, monitoring periods and selected solar measurement stations are presented in Table 2. Multiplying solar panel area with the incoming solar exposure of that particular location during the individual monitoring period, total incoming solar radiation on the solar panel of each house was calculated. Then dividing the solar energy savings of a particular house (obtained from electricity bills) with the total incoming solar radiation on the same house's solar panels, real efficiencies of the installed solar panels in all the four houses were calculated. Also, to evaluate seasonal variations, average daily solar energy produced were compared with average daily household electricity demands (obtained from electricity bills) in different seasons for the selected houses.

To assess maximum achievable solar energies in the eight major Australian cities (Sydney, Melbourne, Brisbane, Canberra, Perth, Darwin, Adelaide and Cairns), the mean annual incoming solar radiation data for each of these cities were collected from the Bureau of

Table 2
Details of selected houses used for solar energy measurements.

Location	Blackburn, Victoria	Niddrie, Victoria	Mypolonga, South Australia	Torrensville, South Australia
System size (kW)	2	5	1.5	0.75
Number of solar panels	12	25	8	4
Area of panels (m^2)	15.88	32	10.24	5.12
Bureau of Meteorology station number	086338	087015	024584	023119
Installation year	2009	2013	2000	2010
Monitoring periods	17/12/2009–18/5/2015	15/11/2013–17/2/2014	8/4/2014–7/7/2014	25/3/2014–24/8/2015