Sustainable Power Generation in Suburban Australia: A Case Study of an Adelaide Household's experience

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Abstract: The "Solar Cities" initiative was introduced on a relatively limited basis in 2007, to trial the efficacy of solar power in reducing the consumption of mains electricity and carbon emissions. The purpose of the Solar Cities trial had been to assess both the technical merits and household behavioural aspects of solar power in predominantly residential applications. This paper analyses an Adelaide case study of a household that participated in this trial . Net consumption of mains electricity by the case study household was reduced to 12% from 2800kWHr annually as a result of a combination of the electricity generated by a 1 kW system (a 60% reduction) and household behavioural modifications (a 28% reduction). The case study findings and case study research methodology were used to suggest how a major research project could be structured to provide a large body of empirical evidence that would underpin future planning policy designed to maximize the uptake of functionally effective and aesthetically attractive local solar electricity systems in Australia's urban areas. The policy implications of this tentative and exploratory research are discussed and the conclusion that emerges is that evidence based urban planning policies are required that mesh effectively with the new environmental policy imperatives being driven at the national level.

Introduction

This paper examines the background to the Solar Cities program and then discusses a case study of a household in metropolitan Adelaide's northeastern suburb of Golden Grove that participated in the Solar Cities program with the installation of a 1kW solar array. The case study explores how the solar array has performed over the past year and the savings in energy consumption that resulted. On the basis of this exploratory work, the paper sets forth preliminary ideas for a larger, more rigorous and robust research project to investigate the feasibility of reducing Australian households' reliance on coal fired generated electricity through behavioural changes and the use of micro solar photovoltaic power systems. The paper then concludes with discussion on the policy implications of achieving a greater uptake of solar power for households in Australia's urban areas.

Background

During the postwar years of infrastructure planning in Australian cities, state governments have tended to assume total responsibility for service provision of basic services such as electricity, water, gas and telecommunications for households and businesses in urban areas. Ironically, prior to the postwar years, a degree of household self sufficiency was commonplace (for example with water and sewage management) with many houses provided with independent rainwater tanks and septic systems even within cities (Neutze, 1978) . The benefits of the industrial age, when applied to electrical power generation, meant that in order to achieve the economies of scale of power production demanded by Australia's burgeoning power hungry cities, the practical responses were to build massive coal fired power stations within or near coal fields closest to Australia's major cities (for example, the Hunter Valley north of Sydney or the La Trobe Valley, east of Melbourne). Reliable, stable power generation was also required around the clock to feed the myriad appliances, gadgets and machines in homes, workplaces and other community buildings. Moreover, given the dangerous nature of electrical energy, it seemed sensible to the authorities to regulate its use and distribution and the easiest way to do this was to centralize its distribution. Furthermore, up until the mid 1980s, consumer electronics were not sufficiently well developed to reliably serve in micro-power generation systems over a lifespan that would be competitive with the 40 year plant life of a major electricity power plant. Hence, it is perhaps not surprising that with the exception of development in remote areas, the need to embrace localized micro power generation systems appeared very limited indeed.

This point is illustrated by the virtually non-existent generation of electrical power from solar energy (mostly local roof mounted solar electricity systems) as late as 2006. In 2006, Australia ranked equal 8th with South Korea in the world in terms of the quantity of solar electricity generated at 31GWHr (a miniscule 0.01% of total Australian electricity consumption) compared with the global leader, Germany with 2220 GWHr (0.4% of total electricity consumed in Germany) (Johnson, 2009) (CIA, 2009). In per capita terms, this translates to approximately 1.4 KWHr/year per Australian compared with nearly 27 KWHr /year per German (CIA, 2009). Given the abundance of sunshine that Australia receives, the potential for greatly increased use of solar power is substantial. In theory, a solar photovoltaic farm 35km by 35km operating at fairly modest efficiencies (15%) could meet all of Australia's electricity needs.

The reluctance of Australian households to embrace solar power is not exclusively a shortcoming of Australian consumers. The Australian building industry is innately conservative, risk averse and cost conscious. Left to market forces, project home builders in particular have not sensed that there is consumer demand and because of this, most of their home designs fail to integrate solar power on the scale needed to meet the energy demands of even small households. Most project home builders have also failed to incorporate technical design support at the home design and purchase stage that would inspire confidence in domestically generated solar power for future householders. Governments at the Commonwealth, State and local levels have until a few years ago not put in place regulations or development incentives that would mandate the inclusion of solar power (where practicable) in new homes. The Commonwealth Government, during the period that John Howard was Liberal Prime Minister (1996-2007), were dismissive about the value of solar power for electrical power generation because it could not meet 'base load' (i.e. electricity on demand) requirements (ABC, 2006b).

The Australian community too is reserved as far as its dominant housing choices are concerned, with many housing consumers opting to choose additional floor-space and luxury items over solar power. In Adelaide, some of the most luxurious project home builders such as Medallion Homes and Samuel James Homes reflect this tendency to favour luxury to the complete exclusion of solar power despite vast roofs (up to nearly $400m^2$) that could easily accommodate substantial domestic solar power systems. Lochiel Park, a new suburban estate of large luxury single family homes in Adelaide's north-eastern suburbs along the Torrens Linear Park is one of the few exceptions to this tendency in new Australian home building. The South Australian Government's Land Management Corporation (LMC), has made it a central tenet of the development ethos for this project that it will be developed according to genuinely 'ecologically sustainable development' principles which is being achieved through low embodied energy, correct building orientation for solar access, good building design for optimal thermal performance and extensive use solar radiation to power domestic solar photovoltaic systems and solar hot water systems (LMC, 2009).

New housing only represents growth of about 2% per annum to Australia's total housing stock (ABS, 2005), hence a major part of the challenge in getting Australian households to think about installing local solar power systems rests with people living in existing households. Because almost all existing homes would be connected to mains power, householders are not compelled by necessity to install a solar power system in the same manner that a failed water heater might compel a householder to consider a solar hot water heater replacement rather than continuing with an electrical hot water system. The fact that most solar power systems are also unable to allow a household to be independent of mains electrical power has represented a significant practical impediment to households considering domestic solar power systems. Households would also be concerned that if the bulk of their electricity consumption was at night, why generate solar power unless it was able to be captured and stored or sold back to the power utility companies? And would power utility companies allow surplus household domestic power to be sold back to them or for such power systems to be connected to their household electricity meter boxes if it resulted in the meter 'running backwards' when in surplus?

Therefore, by 2005, it was perhaps not surprising that the use of solar power for domestic electric power generation in Australia's cities was virtually non-existent. Without strong policy intervention by government to help make solar power a competitive option, there was little to suggest that anything would change in the immediate future. The preceding discussion has highlighted that for both new and existing households, far too many uncertainties and impediments frustrated the take-up of solar power at the household level. This changed towards the end of the Howard era, as the Howard Liberal National government became increasingly desperate to shore up its vote, which was collapsing as home mortgage interest rates appeared to escalate uncontrollably. Australian politics had become increasingly more fractured with the rise of independent politicians and minor political parties such as Nick Xenophon and the Greens likely to hold the balance of power, at least in the Senate. The Howard Government had achieved electoral success with policies targeted at various interest groups in the past (i.e. the "Baby Bonus", "The First Home Owners Grant" and the "Private Health Insurance Rebate") (Errington and Onselen, 2007), hence with pressures from the Greens and environmentalists for Australia to take action on Climate Change, it is perhaps not surprising that a grant or subsidy in the form of the Solar Cities Program was introduced in 2007 to respond to this perceived political threat.

The $75m Solar Cities Program (*offered across five regions in Australia which included 4 local government councils in metropolitan Adelaide*), provided the Howard government with much needed credibility on environmental issues. The Program helped to deflect political attacks from Labor and The Greens. Because Howard's government lost office before the Solar Cities Program was substantially underway, it emerged as too little too late, nevertheless, the success of the program can be gauged by the fact that the program was significantly oversubscribed. Kevin Rudd's Commonwealth Labor Government responded by capping the $8k solar system grant scheme through the imposition of a $100k household income threshold means test in mid 2008 which resulted in community uproar and concerns that the then nascent domestic solar industry would collapse before it had a chance to become established (DEWHA, 2009) .

The Rudd Government, under federal Environment Minister Peter Garrett continued with the means tested $8k solar system grant until 9th of June 2009. A new policy, the Solar Credit Scheme which mimicks the operation of the market was introduced to commence in the 2009/2010 financial year using a system of Solar Credits scaled according to nominated "renewal energy certificate" solar radiation zones (Adelaide falls within Renewable Energy Certificates (REC) zone 3 along with Sydney, Brisbane and Perth). In effect, the direct government financial subsidy for the installation of a domestic solar system was reduced from $8k to $5k, although the scheme was now no longer means tested and Solar Credits could be claimed for commercial and residential investment properties (Garrett 2008). Installers of solar systems normally claim the RECs whilst providing a cash discount to the customer. These RECs are then traded via the Commonwealth Government's REC Registry. The new scheme does not encourage the expansion of existing solar electricity systems with RECs redeemable only on a 1:1 basis, compared to much larger multiples for a new system installation (5:1 for a system of 1.5kW or less) (DEWHA, 2009).

The Solar Cities program has been an undoubted success in terms of its original remit, but in spite of its success, the overall take-up of solar power systems amongst Australian households was still very small indeed (63,000 households or less than 1%) (DEWHA, 2009). Against this policy backdrop, the case study household (the author's) entered the era of residential solar power.

Case Study Research Approach

At the time the case study household made the decision to install solar power in late October 2007, it was something of a leap into the unknown. Without the grant subsidy of $8k off the $12k full retail cost of a 1kW solar photovoltaic system plus Origin Energy's further incentives of a free import/export meter ($300 in value) and a further $1k discount to be included in the scheme (which also implied consent to being monitored as part of the Solar Cities Program survey trial), the value proposition was very uncertain, because of doubts over the long term technological performance (in theory it ranges from 25-35 years) and the payback period. Origin Energy also included a 'gift' in the form of 6 energy saving compact fluorescent light bulbs and a low flow showerhead to stress the need for behavioural change in the amount of energy consumed, rather than just considering how energy is generated. The attractiveness of the scheme is that the relatively low capital outlay ($1.5k on the contract signing and $1.5k on completion of the installation), meant that finance (such as renegotiating the main mortgage over the property or through unsecured personal loans) did not have to be obtained. This somewhat offset the uneasiness of being an early adopter of new relatively technology (at least in the Australian context).

The results of this case study research are as much about the policy challenge of getting households to adopt new technology and the modification in personal behaviour that goes along with this as it is in illustrating how well the technology has worked after a year of operation in the case study household. It should therefore be noted from the outset that this study is exploratory in nature and aims to indicate how a major study might be framed with regard to evaluating solar power generation by households in the Australian urban context. Origin Energy are conducting one such study themselves (which the case study household is part of), but their study is commercial in confidence, technically driven and not necessarily oriented towards resolving the policy challenges that Australian urban planners and policy-makers are most concerned with.

A key focus in this research was to explore document the technical performance of a 1 KW solar power system in a real world application and explore the behavioural responses within the household in response to the operation of the system. The behavioural responses of the household were rational in responding to the price signals of the resulting power available but because every household is unique, scaling up the findings to the general population would introduce potentially large estimation errors. A statistically representative sample of households would be needed for the results to be generalized for the wider population, at least with regard to the aspects of behavioural modification of electricity consumption.

The Australian power company, Origin Energy installed a 1 KW 6 panel Sharp Solar PVC System with a Fronius IG 15 1.5 kW Inverter that feeds solar generated electricity into an import/export meter to allow excess power to be sold back to the electricity grid (see figure 1). Each Sharp NE-Q7E3E panel is rated at a maximum output of 167 watts and 24 volts and has a conversion efficiency of incident sunlight to electrical power of 15%. The total area of the array is approximately $8m^2$. The Inverter includes an LCD data panel that provides instantaneous information of actual power produced by the solar power system in watts, voltage and current (Amps). A reading was taken once a week over a year. The import/export meter by Metropolis has a radio transmitter that transmits data to Origin Energy via a radio receiver attached to phone lines in the nearest Telstra telephone pit. It does this every half hour with data on the household's net power consumption (after deducting any power produced by the solar power system received) and data on the net solar power being exported back to the electricity grid. This data from the import/export meter can later be accessed online via the household's Origin Energy electricity account after 2-3 days. The drawback in this system is that it is impossible to directly ascertain from the import-export meter the actual output of the solar system or the actual and instantaneous power consumption of the household during the time that the solar power system is operational (ie receiving sunlight). This has to be done via the Inverter LCD panel, which can only be read manually.

The optimal position and orientation of photovoltaic panels varies by time of year. For example, the angle above the horizon in summer, is 24^o (*i.e. the latitude of Adelaide* 34^o *minus* 10^o) whereas in winter, it should be more vertical at 49^o (*i.e. the latitude of Adelaide* 34^o *plus* 15^o) (ACC, 2009). For the case study household, the solar panels were fixed to a rigid frame on a concrete tiled roof which had a roof pitch inclined at an angle of 25^o above the horizontal and faced geographic north, a position that was optimal for capturing the summer sun, but less than optimal for winter sun (see figure 1). The system is affected in summer by late afternoon shading from a neighbouring double storey dwelling which partially shades the system for up to 2 hours before sunset. Over the system's first year of installation, the unit has produced 1669 kWHr of power (4.6 kWHr/day). Solar arrays on multi-axis tracking frames can theoretically increase power output by up to 45% over fixed frames because they ensure that optimal orientation relative to the position of the sun is maintained throughout the day and in all seasons but the downside is that they may be prone to mechanical failure (Rubio et al, 2007).

Figure 1here

Case Study Findings

The solar array for the case study was installed at the end of May 2008 and the system became fully operational with an import/export meter from the 19th of July 2008. The 3 bedroom brick veneer house is a standard single storey suburban dwelling typical of many found in metropolitan Adelaide. It has a total habitable floor area of 167m^2, 2.7m high flat ceilings and a 5 star energy rating. By virtue of its northern orientation and the ability to take advantage of cool summer night breezes that drain off the Adelaide Hills (known locally as gully winds), heating and cooling are largely achieved via passive measures, but when weather conditions were extreme, two small split system heat pump reverse cycle air conditioners were used. Water heating is by gas storage heating and cooking is with an electric oven. Lighting throughout the house is largely achieved with energy efficient compact fluorescents. Behaviour modifications in the household were to minimise consumption during periods of sunshine and avoid standby power consumption of electrical appliances. During the study period, the household was predominantly a single person household except for periods when family were visiting. Hence, to be comparable with the power consumption profile of the average Australian household, a correction factor would be needed.

In this case study, approximately 78% (1298 kWHr) of solar generated power over the past year (from 19/7/08 to 18/7/09) was sold back to the grid (initially at 44c/kWHr and then at 50c/kWHr) (see figures 2 and 4). When the solar array was initially installed, daily outputs ranged from 0-3 kWHr in winter to 2-7 kWHr/day in Spring/Summer /Autumn. Figure 3 provides an example profile of optimal daily power output exported to the grid achieved on January 2nd, 2009 when the household was unoccupied and a 24 hour profile in April 2009 which shows power flows to and from the grid. The annual energy consumption of the household was 1993 kWHr, of which 1622 kWHr (81%) was provided by the grid (accredited green power purchased at approximately 17c/kWHr) and the balance of 371 kWHr (19%) was provided directly by the solar array, largely to run a fridge and various standby power items. Figure 4 charts monthly the solar power produced by the system compared with the power consumed off the grid by the household. A daily service charge of approximately $0.39 was paid irrespective of the amount of electricity imported or exported to the grid. In the previous year, annual power consumption for the household was 2800 kWHr. The 31% decrease in power consumption was achieved largely by switching lighting to energy efficient globes and changing the living room heating from electric convection to a reverse cycle high efficiency heat pump unit. The financial performance of the system to date suggests a payback period of 4-5 years.

By way of comparison, the average Adelaide household consumes approximately 15 kWHr/day or 7.0 kWHr/day/person (DEWHA, 2008). Over a year, this would equate to 5475 kWHr of which a 1 kW domestic solar array could offset approximately 30%. However, this assumes that every house in Adelaide is suitable to accept a solar array. In practice, poor orientations of allotment and buildings, awkward roof designs, overshadowing from taller buildings and trees, shared ownership (as in strata titled dwellings), dwellings without external roofs (as in apartment complexes) and dwelling tenure (e.g. rented) are significant impediments to this goal being achieved. There are also technical considerations such as the need to replace metering equipment with smart meters or if homes were to use onsite storage batteries, having sufficient space to accommodate these. Local councils in South Australia no longer require planning approval for domestic solar arrays, nevertheless, if a solar power system requires a structure that alters the roofline of a dwelling, then it becomes a planning concern and planning approval is likely to be determined on the grounds of visual aesthetics rather than the benefit to the environment.

Figure 2 here

Figure 3 here

Figure 4 here

Future Research

This is an ideal time to take stock of the efficacy of the Commonwealth Government's Solar Cities Program and more recently, the RECs Scheme to encourage the take up of local solar power generation systems for homes and businesses.

The research conducted with this case study can be viewed as the equivalent of a pilot study to help demonstrate the potential of smart metering technology to provide exhaustive longitudinal profiling data of household electricity consumption and solar electricity generation over long periods of time without the specific input of a household's occupants to manage the data collection process. The case study was unable to accurately profile the nature of electricity consumption in terms of the specific effects of the use of particular appliances. A household 'electricity consumption diary' would be needed to do this, or alternatively, appliances would need to be connected to a centralized computer monitoring system which would be impractical for many existing households, although technically feasible.

A future research project should encompass two main components of households that have installed local solar power systems:

1. A year long survey of households that were part of the Solar Cities initiative that have installed solar power systems with electronic smart metering to ascertain exactly how electricity was used particularly with regard to how individual electrical appliances affect a household's electricity demand profile. Ultimately, a longitudinal study over 2, 5, 10, 25 and 40 years would be desirable to allow comparative analysis with other forms of centralized power generation. This aspect of the research would require the involvement and co-operation of the Electricity company linked to the particular household's import-export electricity meter that is the subject of the research.

2. Profiling of the nature of the households in the survey sampling frame. This would include:

    a. The nature of surveyed households (i.e. the social occupancy structure and its socio-economic profile);

    b. The physical characteristics of the surveyed households (i.e. roof area with solar access, floor plan, building shell construction, building solar orientation, energy efficiency rating, building orientation, appliances, roof overshadowing and the positioning of the installed solar power system)

    c. An electricity consumption diary, ideally over a year.

    d. Before and after comparisons of electricity consumption for the surveyed households to study the behavioural changes that have occurred and why.

e. Understanding the motivation behind taking up solar power in terms of policy drivers such as solar feed-in tariffs, grants and publicity campaigns to encourage energy conservation in the home and investment in solar power.

An additional facet of the research would be to understand what some of the policy and institutional impediments there are to increased take-up of local solar power systems in residential applications for both new and existing housing. This would include:

1. A critical review of Local Government Development Plans to see how domestic solar power generating potential can be maximized within their jurisdictions.
2. Surveys of residential home builders and lending institutions to determine why solar power systems are rarely incorporated as a standard feature in new homes and what would be needed to make solar power a standard component of every new home that has sufficient solar access.
3. A comprehensive aerial survey of roof spaces urban areas in Australia to ascertain the potential for local solar power systems. This type of survey would have the ultimate aim of providing an estimate of the power that could be generated from local solar power systems.

It would also be of value to have a control survey sample of households physically capable of accommodating solar power systems to determine their reasons for not taking up solar power. Research would also be required to explore the potential for local solar power systems in areas with existing housing. Kellett and Hamilton (2009) with their Australian Research Council funded research on the solar power potential of existing housing in Playford Council in metropolitan Adelaide have provided a useful research methodology and findings as to how this would best be done.

Policy Implications and Conclusions

This research has only focused on a single household case study in exploring the practicality of domestic solar power, nevertheless, it has been done in the spirit of a best case scenario and it is an interesting example of an outcome that is purely the result of a government policy initiative (the Solar Cities Program) to encourage the take-up by Australian households of solar power.

Rough projections would suggest that out of a residential building stock of approximately 400,000 single family owner occupied homes in metropolitan Adelaide (ABS, 2009), even if only 25% of these homes were suitable for a 1 kW solar system, then approximately 100,000 homes could be fitted with a solar array, which theoretically would yield 160gW of power savings per year (or approximately 166,000 tonnes of carbon dioxide emissions annually). Overall, this would make a predicted saving of between 2-3% of metropolitan Adelaide households' consumption of power and production of carbon emissions. (DEWHA, 2009). Still, in the case study household, behavioural changes alone, were able to reduce electricity consumption by 30%, and it is therefore conceivable that with price signals to encourage householders to sell their solar electricity back to the grid, reductions of 50-60% in electricity consumption are achievable. Whilst a strategy to improve the take-up of solar power at the domestic level would appear to have a limited but important role in reducing Australia's use of fossil fuels and carbon emissions to meet residential power demands, this research indicates that much more work is needed to understand why this is so.

Building roof design looms as a significant planning issue in future. The current practice of using pitched roofs on domestic dwellings results in greatly reduced opportunities to mount solar arrays (see aerial image in figure 1), particularly when there may not be a large inclined surface at the correct angle facing north or where the roof geometry has complicated valleys and folds. Ideally, a saw tooth pattern or horizontal surface of roofing may work better because it would allow even small house floorplans (i.e. of as little as $100m^2$) to easily accommodate solar panels. Horizontal roofs would allow greater flexibility in designing mechanized solar panels that automatically align with the optimal angle of solar incidence. This would require an array or elements in an array being able to rotate from facing due east to north and then due west in summer and also varying the pitch as the angle of solar incidence varies during the year.

Planners in the past have tended to have rigid policy positions on building aesthetics. Domestic buildings that are designed purely to maximize solar array capacity and performance could appear ugly or far too utilitarian. There are other interesting policy issues with promoting solar power in residential areas such as solar access rights for existing solar arrays (which could conflict with policies to increase residential densities) and significant tree protection legislation (making it illegal to remove or cut down large established trees). New planning policies are needed that consider access to sunlight and that avoid ill-considered development or tree plantings from rendering existing solar arrays functionally useless in the future.

The other part of the policy framework is financial incentives. The new policy's "carrots" are RECs and a feed-in tariff that is more than double the current usual charge for electrical power. RECs mainly benefit the supplier who is then meant to pass this saving on to the householder or recipient of the solar array. The flaw in the current system is that RECs do not make it clear to consumers that solar power is subsidized and the owner of a REC has no control over whether the solar array remains functional. RECs also fail to compel consumers of coal based power to reconsider their choice and the Rudd government's carbon pricing scheme is as disconnected from the consumer as the RECs concept is.

The feed-in tariffs for solar generated power are state government policy areas and hence there is variation across Australia (Energy Matters, 2009). In South Australia, the policy is based on the net effect every half hour, hence it is possible (as was demonstrated in the case study) to realize a substantial financial benefit when the sun is shining, even if more power is consumed at night off the grid. The problem with this metering approach is that it does not allow the utility company to ascertain exactly what the gross power performance of a solar array is nor what the actual power consumption of a household is. Having payments based on gross power as is done in Germany (either consumed from the grid or sold back to the grid) would provide potential solar power consumers with greater transparency and provide more certainty about the benefits of going solar for householders (Wüstenhagen & Bilharz, 2004).

Solar power for rental accommodation also appears to be a policy blind spot. In existing medium density accommodation where two or more dwellings share a common roof structure, there is an absence of policy or a covenant structure that would allow interested parties (i.e. residents, owners, investors and tenants) to invest in solar power. In situations such as these, policies such as RECs and preferential feed-in tariffs are designed for owner occupiers but what happens to tenants? Tenants consume power but without receiving a share in the feed-in tariff, they have no incentive to minimize consumption during the day and from the grid. A policy that could perhaps manage this is to mandate that any roof area capable of accepting a solar array be made available to utility companies who could rent the space for solar arrays that they would own. Owners of buildings that choose not to make their roof space available would be taxed at a rate commensurate with the loss of this solar power potential. The situation is somewhat trickier with multiple households under a common roof if a shared solar array were to be used. The easiest way to manage this would be to either have separate solar arrays and inverters for each household or to devise a new system that notionally provides a share of the solar array but at the same time, the utility company would need to recognize that if one householder consumed more than their share, then the other householders would not lose their rights to the preferential feed-in tariff with the utility company effectively providing grid power for the high power consuming household.

In conclusion, Australia is potentially in the midst of a seismic shift in energy and environmental policies that will have substantial ramifications for the planning of Australia's urban areas and the nature of its building stock. To some extent, the Commonwealth Government's international obligations under any future global climate change agreement will force the introduction of new environmental policies without the benefit of sound empirical research evidence to validate their efficacy in reducing the energy and carbon emissions profiles of Australia's cities. A significant unknown is how planning in Australia's cities can best respond to some of these environmental policies to help realize the maximum reduction in carbon emissions and solar electricity output from the residential housing sector. The pilot case study and suggested direction for future empirically based research discussed in this paper has provided a basis for future evidence based planning policies that will help to ensure that a better understanding of the role of household behaviour is obtained in using residential domestic solar electricity systems and that the installation of such systems is optimized in Australian cities.

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Location of I kW solar power array

Source: Google Earth, 2009

Figure 1: Solar power installation for case study dwelling (from left, solar array, inverter and smart meter)

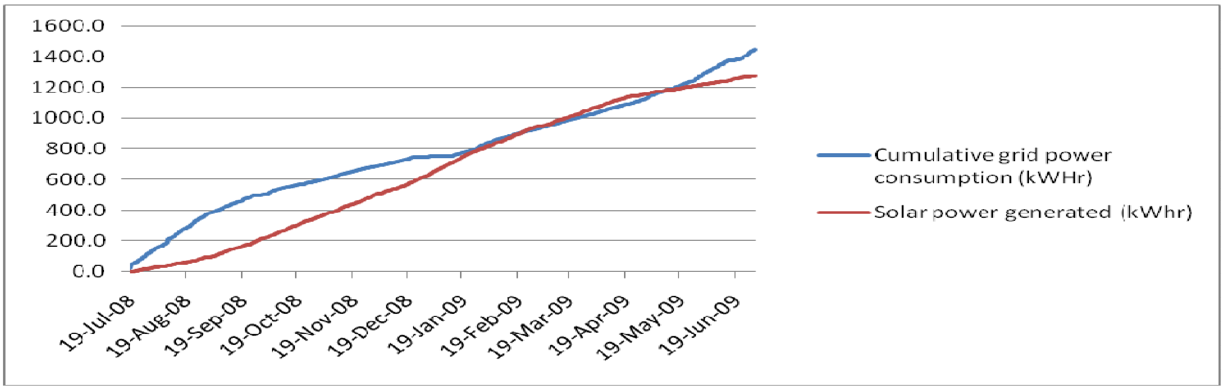

Figure 2: Cumulative grid power consumption versus net solar power fed back to the grid.

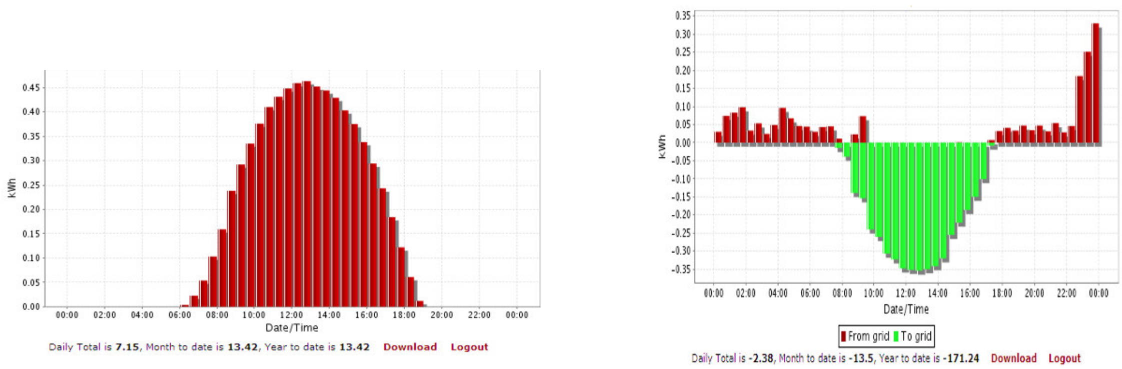

Figure 3: Online screen-grabs showing half hourly power (kWHr) profiles. The chart on the left illustrates the best performance achieved (on 2/1/09 with a 39C maxima and 11 hours of sunshine) and on the right, a typical 24 hour profile during April 2009) (Source: Origin Energy customer account)

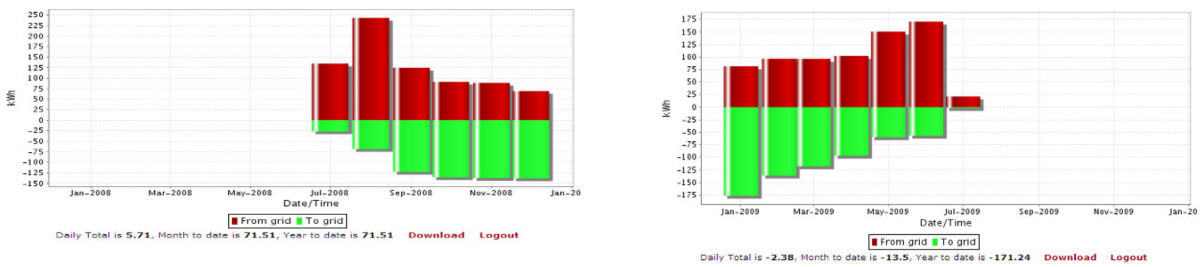

Figure 4: Monthly profiles showing net power consumption (kWHr) (July 2008-July 2009)

(Source: Origin Energy customer account)